राष्ट्रीय क्वांटम मिशन (NQM) अंतर्गत महाराष्ट्रात क्वांटम तंत्रज्ञान व कौशल्यविकास उपक्रमांची अंमलबजावणी करणेबाबत तसेच सदर उपक्रमांतर्गत खरेदी करिता प्रशासकीय मान्यता देणेबाबत.

महाराष्ट्र शासन

उच्च व तंत्र शिक्षण विभाग

शासन निर्णय क्र. १३८१८७८/ HTED-११०११(११)/१३/२०२५-MHT-(TE-२)

हुतात्मा राजगुरु चौक, मादाम कामा रोड,

मंत्रालय, मुंबई ४०० ०३२.

दि. १४ मे, २०२६

संदर्भ: १. तंत्र शिक्षण संचालनालयाचे पत्र क्र. DTEM-D१७०TEQP/६०/२०२६-DESK१७,
दिनांक: २४ मार्च, २०२६

२. मा.मुख्य सचिव यांच्या अध्यक्षतेखालील उच्चाधिकार समितीची (HPC) बैठक, दि.२३.०४.२०२६

प्रस्तावना :-

क्वांटम तंत्रज्ञान हा वैज्ञानिक व औद्योगिक प्रगतीचा पुढील टप्पा आहे. संगणक तंत्रज्ञान होणाऱ्या बदलामुळे जागतिक स्तरावर मोठ्या प्रमाणात प्रशिक्षित मनुष्यबळाची आवश्यकता निर्माण होणार आहे. क्वांटम मेकॅनिक्सच्या तत्त्वांचा लाभ घेऊन, क्वांटम संगणन, संप्रेषण, सेन्सिंग आणि मटेरियल्स या तंत्रज्ञानांना औषधनिर्मिती, वित्तीय मॉडेलिंग, राष्ट्रीय सुरक्षा आणि हवामानाचा पूर्वानुमान यांसारख्या विविध क्षेत्रांमध्ये क्रांतिकारी बदल घडविण्याची क्षमता आहे.केंद्र शासनाने राष्ट्रीय क्वांटम मिशन (NQM) सुरू केले आहे. राज्यात क्वांटम तंत्रज्ञान प्रशिक्षित मनुष्यबळ निर्माण करण्यासाठी I-Hub Quantum Technology Foundation, भारतीय विज्ञान शिक्षण आणि संशोधन संस्था, पुणे (IISER) ही संस्था मुख्य केंद्र (Hub) म्हणून तर उपकेंद्र (Spoke) संस्था म्हणून सीओईपी तंत्रज्ञान विद्यापीठ, पुणे, डॉ. बाबासाहेब आंबेडकर तंत्रशास्त्र विद्यापीठ लोणेरे, (DBATU), वीरमाता जिजाबाई तंत्रज्ञान संस्था, मुंबई (VJTI), आणि विश्वेश्वरय्या राष्ट्रीय तंत्रज्ञान संस्था, नागपूर (VNIT), यांच्या माध्यमाने राज्यात क्वांटम तंत्रज्ञान व कौशल्यविकास उपक्रमांची अंमलबजावणी करण्याची बाब शासनाच्या विचाराधीन होती.

शासन निर्णय -

केंद्र शासनाच्या राष्ट्रीय क्वांटम मिशन (NQM) अंतर्गत राज्यात क्वांटम तंत्रज्ञान व कौशल्यविकास उपक्रमांची अंमलबजावणी करण्याबाबत मा.मुख्य सचिव यांच्या अध्यक्षतेखालील

उच्चाधिकार समितीच्या दि.२३.०४.२०२६ रोजीच्या बैठकीमधील मान्यतेनुसार व सोबत जोडलेल्या सविस्तर प्रकल्प अहवालानुसार खालीलप्रमाणे निर्णय घेण्यात येत आहे -

I. राज्यात क्वांटम तंत्रज्ञान व कौशल्यविकास उपक्रम दोन वर्षात राबविण्यात येणार असून आय-हब, क्वांटम तंत्रज्ञान फाउंडेशन (I-Hub, QTF), IISER, पुणे या संस्थेस ९.५ कोटी, सीओईपी तंत्रज्ञान विद्यापीठ पुणे, डॉ. बाबासाहेब आंबेडकर तंत्रशास्त्र विद्यापीठ, लोणेरे व वीरमाता जिजाबाई तंत्रज्ञान संस्था, मुंबई या तीन संस्थाना प्रत्येकी रु. २.५ कोटी आणि विश्वेश्वरय्या राष्ट्रीय तंत्रज्ञान संस्था, नागपूर या संस्थेसाठी रु. ३.० कोटी असा एकूण रु. २० कोटी (अक्षरी रु. वीस कोटी मात्र) इतका निधी मंजूर करण्यात येत आहे.

II. सदरचा निधी हा तंत्रशिक्षण संचालनालयाने संदर्भाधिन पत्रान्वये सादर केलेल्या विस्तृत प्रकल्प अहवालात नमूद बाबींसाठी खर्च करण्यास प्रशासकीय मान्यता देण्यात येत आहे. सदर संस्थेची खरेदी प्रक्रिया विहित शासन नियमानुसार तंत्रशिक्षण संचालनालय स्तरावर राबवून वित्तीय मान्यतेसाठी प्रस्ताव तंत्रशिक्षण संचालनालयाने शासनास सादर करावा.

III. खरेदी प्रक्रियेसंदर्भातील निविदा विषयक बाबी उदा. Bill of Quantity (BoQ), Request for Proposal (RFP) तसेच निविदा प्रक्रिया प्रभावीपणे पार पाडण्यासाठी, शासनाच्या माहिती तंत्रज्ञान विभागामार्फत (DIT) आदेश क्रमांक: GAD-मातंसं ०१७/१२९/२०२५/Comp No. १४४६९२१, दि. १९.१२.२०२५ अन्वये नियुक्त केलेल्या Primus Partners Pvt. Ltd., मुंबई या संस्थेची सेवा घेण्यात यावी.

२. राज्यातील तंत्रशिक्षण संस्थांना क्वांटम शिक्षण, संशोधन आणि उद्योग सहकार्याच्या क्षेत्रात सक्षम बनवून "क्वांटम रेडी महाराष्ट्र" हा दृष्टीकोन साकार करण्याच्या अनुषंगाने या उपक्रमाचे मुख्य उद्दिष्टे पुढीलप्रमाणे आहेत:

२.१ उपक्रमांतर्गत करण्यात येणारी कार्यवाही -

I. क्वांटम तंत्रज्ञान क्षेत्रात प्रशिक्षित व आधुनिक संशोधन पद्धतींमध्ये निपुण प्राध्यापक घडविण्याच्या उद्देशाने, I-Hub Quantum Technology Foundation, IISER पुणे येथे संरचित व प्रगत प्रशिक्षण कार्यक्रम राबविण्यात येईल. या कार्यक्रमांतर्गत प्राध्यापकांना क्वांटम संगणन, अल्गोरिदम, क्वांटम सेन्सिंग व क्वांटम मटेरियल्स या प्रमुख क्षेत्रांमध्ये सखोल ज्ञान व व्यावहारिक कौशल्ये प्राप्त होतील. प्रशिक्षण पूर्ण केलेले प्राध्यापक आपल्या-आपल्या संस्थांमध्ये *Master Trainer* म्हणून कार्य करून पुढील स्तरावर विद्यार्थ्यांना ज्ञानविस्तार करतील.

II. सदर उपक्रमांतर्गत सुमारे १२० प्राध्यापकांचे (पहिल्या वर्षी ४५ व दुसऱ्या वर्षी ७५) प्रशिक्षण करण्याचे नियोजन असून, हे प्रशिक्षण टप्प्याटप्प्याने राबविण्यात येईल. तसेच, राष्ट्रीय शिक्षण धोरण २०२० (NEP २०२०) अनुषंगाने सहभागी संस्थांमध्ये (सीओईपी तंत्रज्ञान विद्यापीठ, पुणे;

डॉ. बाबासाहेब आंबेडकर तंत्रशास्त्र विद्यापीठ, लोणेरे; वीरमाता जिजाबाई तंत्रज्ञान संस्था, मुंबई व विश्वेश्वरय्या राष्ट्रीय तंत्रज्ञान संस्था, नागपूर) अभियांत्रिकी पदवी अभ्यासक्रमात क्वांटम तंत्रज्ञानाशी संबंधित विषय *Minor* स्वरूपात उपलब्ध करून दिले जातील. त्याचबरोबर पदव्युत्तर पदवी (PG) व पदव्युत्तर पदविका (PG Diploma) तसेच पदव्युत्तर (PG) स्तरावर ऐच्छिक विषय (Electives) सुरू करण्यात येतील.

III. या उपक्रमांतर्गत सहभागी संस्थांमध्ये विस्तृत प्रकल्प अहवालात नमूद केल्याप्रमाणे आवश्यक प्राथमिक पायाभूत सुविधा उभारण्यात येतील. यामध्ये प्रयोगशाळा उपकरणे, उच्च क्षमतेची संगणकीय साधने, सिम्युलेशन सॉफ्टवेअर, क्लाऊड-आधारित क्वांटम प्लॅटफॉर्म्स तसेच प्रशिक्षण मॉड्यूल्सचा समावेश असेल, ज्यामुळे अध्यापन, प्रशिक्षण व संशोधन उपक्रमांना चालना मिळेल.

IV. सहभागी संस्थांकडून निवड करण्यात आलेले प्राध्यापक I-Hub Quantum Technology Foundation, IISER पुणे येथे आयोजित सखोल प्रशिक्षण कार्यक्रमात सहभागी होतील. प्रशिक्षण पूर्ण केल्यानंतर ते संबंधित संस्थांमध्ये अध्यापन व प्रशिक्षणाची जबाबदारी पार पाडतील तसेच नव्याने सुरू करण्यात येणारे क्वांटम विषयक अभ्यासक्रम प्रभावीपणे राबवतील.

V. सदर उपक्रम प्रभावीपणे राबविण्यासाठी शैक्षणिक वर्ष २०२६-२७ पासून संबंधित संस्थांमध्ये क्वांटम तंत्रज्ञान विषयक अभ्यासक्रम सुरू करण्यास संबंधित संस्थांनी प्राधिकरणाकडून आवश्यक मंजुरी प्राप्त करून घ्यावी.

२.२ निधी वितरणाची अट व टप्पे (Milestone-based Fund Release Conditions) -

सदर उपक्रमासाठी मंजूर करण्यात येणारा निधी हा टप्प्याटप्प्याने (Milestone-based) वितरित करण्यात येईल. प्रत्येक टप्प्यातील निधी वितरण हे संबंधित उद्दिष्टपूर्ती व प्रगती अहवालाच्या समाधानकारक पडताळणीवर अवलंबून राहील.

(अ) पहिला टप्पा (वित्तीय वर्ष २०२६-२७): पहिल्या वर्षातील निधीचा उपयोग

सदर उपक्रमाच्या पहिल्या वर्षात प्राध्यापक क्षमता विकास, मूलभूत पायाभूत सुविधा निर्मिती व शैक्षणिक उपक्रमांची सुरुवात यावर मुख्य भर राहील. याकरिता पहिल्या टप्प्यात रु १०.६३ कोटी (I-Hub Quantum Technology Foundation, IISER, पुणे: रु. ५.०८ कोटी, सीओईपी तंत्रज्ञान विद्यापीठ, पुणे; रु.१ कोटी, डॉ. बाबासाहेब आंबेडकर तंत्रशास्त्र विद्यापीठ, लोणेरे; रु.०.६७ कोटी, वीरमाता जिजाबाई तंत्रज्ञान संस्था, मुंबई: रु.१.७५ कोटी व व्हीएनआयटी, नागपूर; रु. २.१३ कोटी) इतक्या निधीस मान्यता देण्यात असून या निधीचा उपयोग पुढीलप्रमाणे करण्यात यावा.

I. IISER पुणे येथे केंद्रीकृत क्वांटम सिम्युलेशन हब स्थापन करणे, क्लाऊड-आधारित क्वांटम संगणन सुविधा उपलब्ध करणे, तसेच सहभागी संस्थांतील (Spoke Institutes) अध्यापकांसाठी प्रशिक्षण कार्यक्रम (FDPs) राबविणे.

II. सहभागी संस्थांमध्ये मूलभूत प्रयोगशाळा पायाभूत सुविधा उभारणे (क्वांटम ऑप्टिक्स व क्वांटम क्रिप्टोग्राफी प्रात्यक्षिक साठी उपकरणे, फोटॉनिक्स प्रयोगशाळा व ट्रॅप्ड-आयन प्रात्यक्षिक प्रणाली उभारणीसाठी आवश्यक उपकरणे, GPU आधारित संगणकीय साधने व क्वांटम शिक्षण उपकरणे तसेच सिम्युलेशन सुविधा उपलब्ध करणे). तसेच सहभागी संस्थांसाठी आवश्यक क्लाऊड सदस्यता घेणे.

(ब) दुसरा टप्पा (वित्तीय वर्ष २०२७-२८): दुसऱ्या वर्षातील निधी हा उपक्रमाच्या फल निष्पत्तीच्या प्रगती आधारित असेल

I. सदर उपक्रमाच्या दुसऱ्या वर्षात सुद्धा प्राध्यापकांचे प्रशिक्षण पूर्ण करणे, सहभागी संस्थांमध्ये क्वांटम तंत्रज्ञान विषयक अभ्यासक्रम सुरू करणे, विद्यार्थ्यांचा या विषयात सहभाग वाढविणे तसेच प्रयोगशाळा कार्यान्वित यावर मुख्य भर राहील.

II. याकरिता उपक्रमाच्या दुसऱ्या वर्षी रु. ९.३७ कोटी (I-Hub Quantum Technology Foundation, IISER, पुणे: रु. ४.४२ कोटी, सीओईपी तंत्रज्ञान विद्यापीठ, पुणे: रु. १.५० कोटी, डॉ. बाबासाहेब आंबेडकर तंत्रशास्त्र विद्यापीठ, लोणेरे: रु.१.८३ कोटी, वीरमाता जिजाबाई तंत्रज्ञान संस्था, मुंबई: रु.०.७५ कोटी व व्हीएनआयटी, नागपूर: : रु. ०.८७ कोटी) इतक्या निधीची आवश्यकता असून हा निधी उपक्रमाच्या पहिल्या वर्षात खालील प्रगती साध्य झाल्यानंतर वितरित करण्यात येईल.

- उपक्रमाच्या पहिल्या टप्प्यात नमूद क्वांटम उपक्रमासाठी आवश्यक असलेली प्रयोगशाळा व संगणकीय पायाभूत सुविधा उभारणी
- DPR मध्ये नमूद केल्याप्रमाणे सहभागी spoke संस्थांतील ४५ प्राध्यापकांसाठी प्रशिक्षण पूर्ण
- क्लाऊड/सिम्युलेशन सुविधा कार्यान्वित
- पदवी स्तरावर क्वांटम विषयक Minor अभ्यासक्रमाची तयारी
- प्रगती अहवाल (Progress Report) व वित्तीय उपयोगिता प्रमाणपत्र (UC) सादर

३. सुकाणू समितीचे गठन -

राज्यातील क्वांटम तंत्रज्ञानाच्या सर्वसमावेशक विकासासाठी धोरणात्मक निर्णय, शासनाशी समन्वय आणि क्वांटम उपक्रमाचा प्रगती आढावा घेण्याच्या अनुषंगाने खालीलप्रमाणे सुकाणू समिती गठीत करण्यात येत आहे.

अ.क्र.	पदनाम	समितीतील पदनाम
१	अपर मुख्य सचिव/प्रधान सचिव, उच्च व तंत्र शिक्षण विभाग	अध्यक्ष
२	प्रधान सचिव/सचिव,इलेक्ट्रॉनिक्स, माहिती तंत्रज्ञान व कृत्रिम बुद्धिमत्ता विभाग	सदस्य
३	प्रधान सचिव, वित्त विभाग	सदस्य
४	मुख्य कार्यकारी अधिकारी (CEO), महाराष्ट्र इन्स्टिट्यूशन फॉर ट्रान्सफॉर्मेशन - मित्र (MITRA)	सदस्य
५	सहभागी चारही spoke संस्थांचे संस्था प्रमुख	सदस्य
६	संचालक, IITB, मुंबई यांचे प्रतिनिधी (विषय तज्ञ)	सदस्य
७	उद्योग क्षेत्रातील नामांकित तज्ञ	सदस्य
८	मुख्य कार्यकारी अधिकारी (CEO), I-Hub, क्वांटम तंत्रज्ञान फाउंडेशन (QTF), IIISER, पुणे	सदस्य
९	संचालक, तंत्र शिक्षण, महाराष्ट्र राज्य, मुंबई	सदस्य सचिव

३.१ सुकाणू समितीचे कार्यक्षेत्र (Scope of Work) खालीलप्रमाणे राहील -

सुकाणू समिती ही सदर क्वांटम तंत्रज्ञान उपक्रमासाठी धोरणात्मक मार्गदर्शन करणारी प्रमुख संस्था म्हणून कार्य करील. समितीची प्रमुख कार्ये पुढीलप्रमाणे असतील:

I. उपक्रमासाठी दीर्घकालीन धोरणात्मक दिशा (Strategic Direction) निश्चित करणे व राज्याच्या प्राधान्यक्रमांशी सुसंगती राखणे.

II. समन्वय समितीमार्फत द्विमासिक किंवा आवश्यकते नुसार आढावा बैठकांचे आयोजन करणे, उपक्रमाच्या प्रगतीचा आढावा घेणे तसेच उद्दिष्टे व अपेक्षित परिणामांची पूर्तता होत आहे याची खात्री करणे.

III. क्वांटम तंत्रज्ञान क्षेत्रातील राष्ट्रीय व आंतरराष्ट्रीय घडामोडींचा अभ्यास करून धोरणात्मक मार्गदर्शन करणे.

IV. राज्यातील शैक्षणिक संस्था, संशोधन संस्था व उद्योग यांच्यात समन्वय व सहकार्य वाढविणे.

V. उपक्रमाच्या अंमलबजावणीसाठी आवश्यक असलेल्या धोरणात्मक निर्णयांना मान्यता देणे व मार्गदर्शन करणे.

VI. निविदा प्रक्रिया, खरेदी प्रक्रिया प्रभावीपणे राबविणे बाबत मार्गदर्शन करणे.

VII. क्वांटम उपक्रमांतर्गत संशोधन, नवोन्मेष (Innovation) व स्टार्टअप्सना चालना देण्यासाठी आवश्यक उपाययोजना सुचविणे.

VIII. केंद्र शासनाच्या योजनांशी (उदा. National Quantum Mission) सुसंगती व समन्वय सुनिश्चित करणे.

IX. आवश्यकतेनुसार नवीन उपक्रम, भागीदारी (PPP/CSR) व गुंतवणूक संधी सुचविणे.

४. समन्वय समितीचे गठन -

सुकाणू समितीप्रमाणे क्वांटम तंत्रज्ञान उपक्रमांतर्गत समन्वय आणि अंमलबजावणीच्या अनुषंगाने मुख्य कार्यकारी अधिकारी (CEO), I-Hub, क्वांटम तंत्रज्ञान फाउंडेशन (QTF), IISER, पुणे यांनी सर्व सहभागी संस्थांचे प्रतिनिधी असलेली एक समन्वय समिती (Coordination Committee) त्यांचे स्तरावर गठीत करावी.

५. लेखाशीर्ष

सदर उपक्रमाच्या अंमलबजावणीसाठी लागणारा निधी हा तंत्र शिक्षण संचालनालयाच्या खालील लेखाशिर्षा अंतर्गत उपलब्ध करुन दिला जाईल.

मागणी क्र. डब्ल्यु-३,
लेखाशिर्ष - २२०३ तंत्रशिक्षण,
१०४ अशासकीय तंत्र महाविद्यालये व संस्था यांना सहाय्य
(०२) परिरक्षण अनुदान
(०२)(०३) अभियांत्रिकी महाविद्यालये (कार्यक्रम) (२२०३ ०१९४)
३१, सहाय्यक अनुदाने (वेतनेतर)

६. सदर शासन निर्णय मा.मुख्य सचिव यांच्या अध्यक्षतेखालील उच्चाधिकार समितीच्या दि.२३.०४.२०२६ रोजीच्या बैठकीमधील मान्यतेस अनुसरून निर्गमित करण्यात येत आहे.

सदर शासन निर्णय महाराष्ट्र शासनाच्या www.maharashtra.gov.in या संकेतस्थळावर उपलब्ध करण्यात आला असून त्याचा संकेताक २०२६०५१४१५३४४७२३०८ असा आहे. हा निर्णय डिजीटल स्वाक्षरीने साक्षांकित करुन काढण्यात येत आहे.

महाराष्ट्राचे राज्यपाल यांच्या आदेशानुसार व नावाने.

SANTOSH PUNAMCHAND KHORGADE

Digitally signed by SANTOSH PUNAMCHAND KHORGADE
DN: CN = SANTOSH PUNAMCHAND KHORGADE, C = IN, S = Maharashtra, O = GOVERNMENT OF MAHARASHTRA, OU = Higher and Technical Education
Date: 2026.05.14 18:21:17 +05'30'

(संतोष खोरगडे)

सह सचिव,महाराष्ट्र शासन

प्रत,

१. मा. राज्यपाल, महाराष्ट्र राज्य, यांचे प्रधान सचिव, राजभवन, मुंबई
२. मा.मुख्यमंत्री, महाराष्ट्र राज्य यांचे प्रधान सचिव, मंत्रालय, मुंबई

३. मा. उपमुख्यमंत्री, महाराष्ट्र राज्य, यांचे सचिव, मंत्रालय, मुंबई

४. मा.मंत्री (उच्च व तंत्रशिक्षण) यांचे खाजगी सचिव, मंत्रालय,मुंबई.

५. मा.मुख्य सचिव, यांचे वरिष्ठ स्वीय सहायक, मंत्रालय, मुंबई

६. सर्व अपर मुख्य सचिव/प्रधान सचिव/सचिव, मंत्रालय, मुंबई

७. संचालक, तंत्र शिक्षण संचालनालय, मुंबई

८. क्वांटम तंत्रज्ञान उपक्रमात सहभागी सर्व संस्था प्रमुख

९. विभागीय सहसंचालक उच्च व तंत्र शिक्षण विभाग, पुणे, मुंबई, जळगाव, नागपूर, अमरावती

१०.महालेखापाल, (लेखापरीक्षा/लेखा व अनुज्ञेयता), महाराष्ट्र-१ व २ , मुंबई व नागपूर,

११.सबंधित जिल्हा कोषागार अधिकारी,

१२.अधिदान व लेखा अधिकारी, मुंबई-३२.

१३.निवासी परिक्षा लेखा अधिकारी,मुंबई

१४.निवडनस्ती (तांशि-२)

महाराष्ट्र शासन

I-HUB QUANTUM TECHNOLOGY FOUNDATION

Project Proposal

Maharashtra Quantum Technology Mission

Establishing a Quantum Technology Capability

In Hub-Spoke Model withI Hub QTF IISER Pune as a HUB VNIT Nagpur, DBATU Lonere, COEP Tech University Pune and VJTI Mumbai as Spokes

Bringing Together Academic and Research Institutions, Government, Industries, and Youth for the Development of Maharashtra through Quantum Technologies

Submitted to

The Government of Maharashtra

I Hub Quantum Technology Foundation, IISER Pune

March 2026

Abbreviations

AICTE	All India Council for Technical Education
CAPEX	Capital Expenditure
COEP	COEP Technological University
DBATU	Dr. Babasaheb Ambedkar Technological University
DRDO	Defence Research and Development Organisation
DST	Department of Science and Technology
DTE	Directorate of Technical Education
FDP	Faculty Development Programme
FY	Financial Year
GoM	Government of Maharashtra
GPU	Graphics Processing Unit
H&TE	Higher and Technical Education
HPC	High Performance Computing
I-Hub QTF	I-Hub Quantum Technology Foundation
IISER	Indian Institute of Science Education and Research
LMS	Learning Management System
MeitY	Ministry of Electronics and Information Technology
MQTM	Maharashtra Quantum Technology Mission
NAS	Network Attached Storage
NISQ	Noisy Intermediate-Scale Quantum
NMiCPS	National Mission on Interdisciplinary Cyber-Physical Systems
NQM	National Quantum Mission
NSCS	National Security Council Secretary

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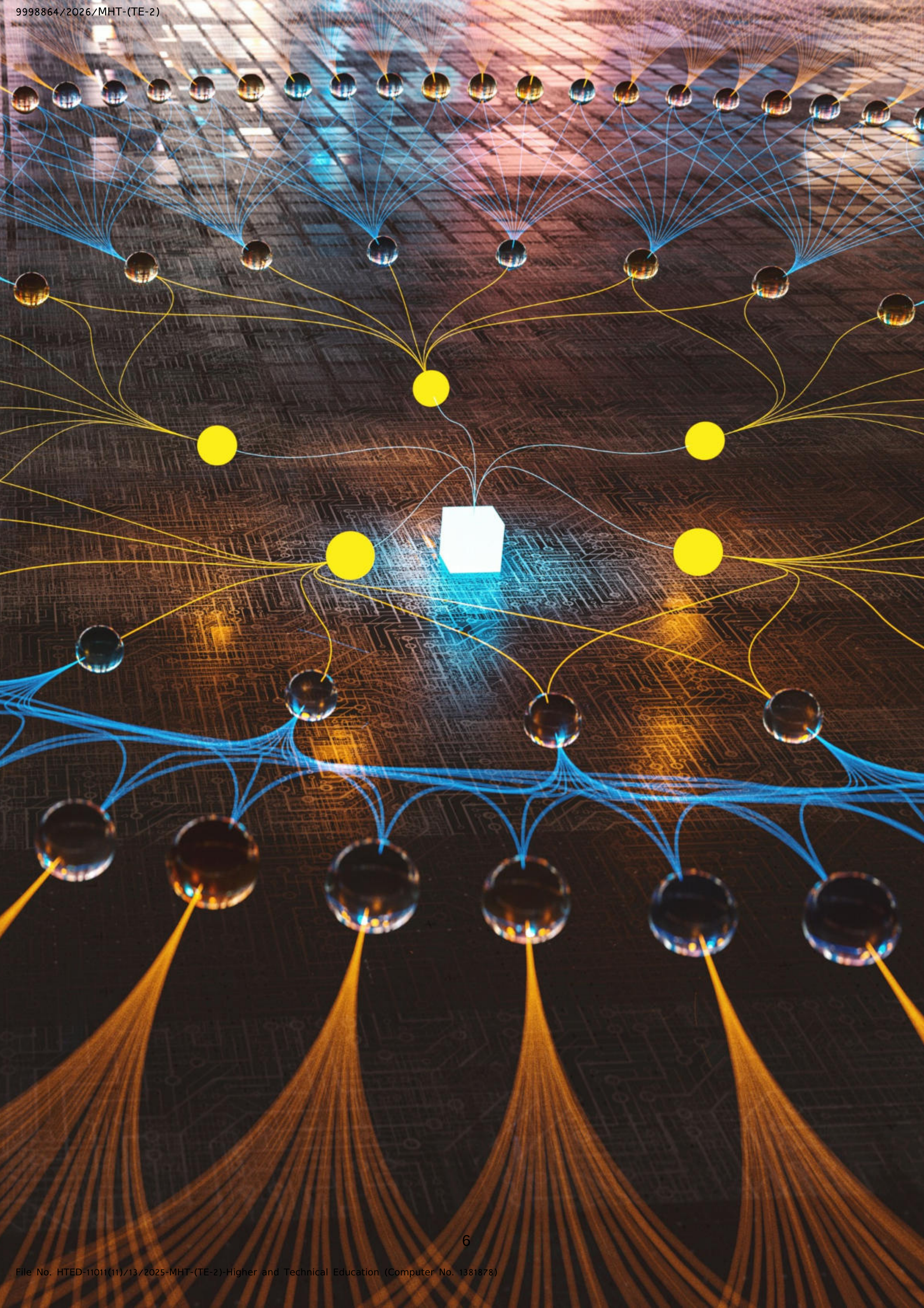


Executive Summary

The Government of Maharashtra proposes the Maharashtra Quantum Technology Mission (MQTM) to build institutional capability in quantum technologies through a collaborative hub-and-spoke model involving leading technical institutions in the state. The initiative will be anchored by the I-Hub Quantum Technology Foundation (I-Hub QTF) at IISER Pune as the Hub, with Visvesvaraya National Institute of Technology (VNIT) Nagpur, Dr. Babasaheb Ambedkar Technological University (DBATU) Lonere, COEP Technological University Pune, and Veermata Jijabai Technological Institute (VJTI) Mumbai serving as Spoke institutions. The mission seeks to bring together academic institutions, government, industry, and students to build capability in emerging quantum technologies.

The initiative aims to build a strong foundation in quantum technology education, research, and infrastructure across participating institutions. The mission focuses on developing a quantum-ready faculty ecosystem, integrating modular quantum technology curriculum across state institutions, and creating shared and local infrastructure for teaching and research.

The program will be implemented in a phased manner between June 2026 and December 2027. During this period, faculty training programs will be conducted in multiple cohorts using a six-month hybrid model that combines residential laboratory sessions and online instruction. Quantum technology curriculum aligned with AICTE norms and the National Quantum Mission will be developed and introduced within B.Tech and M.Tech programs across participating institutions.

To support teaching and research activities, the initiative will establish both centralised and distributed infrastructure. A centralised quantum simulation laboratory will be established at I-Hub QTF, IISER Pune, providing access to simulation environments and cloud-based quantum computing platforms. In addition, experimental quantum teaching laboratories will be established at DBATU Lonere, VJTI Mumbai, COEP Technological University Pune, and VNIT Nagpur, equipped with quantum education kits, simulation workstations, and local server-based simulators to support hands-on learning and experimentation. Phase-1 of the Maharashtra Quantum Technology Mission requires an estimated Government of Maharashtra grant of approximately ₹20 crore over two financial years (FY 2026-27 and FY 2027-28).

The investment will support faculty development programs, the establishment of quantum teaching laboratories at the spoke institutions, and the creation of a centralised simulation, training, and program management infrastructure at I-Hub QTF, IISER Pune. In the subsequent phase 2, the Mission will focus on strengthening industry–academia collaboration by establishing Quantum Research Parks and shared technology infrastructure across the state.

The initiative is expected to train over 120 faculty members across participating institutions and enable over 320 undergraduate and postgraduate students to participate in quantum technology programs. The program introduces a UG Minor in Quantum Technology starting AY 2026-27 and launches an M. Tech program in Quantum Technology starting AY 2027-28, strengthening Maharashtra's quantum technology talent pipeline.

The program will also enable access to quantum simulation platforms and cloud-based quantum computing systems, support student research and innovation, and contribute to the development of a skilled workforce in quantum technologies in Maharashtra.

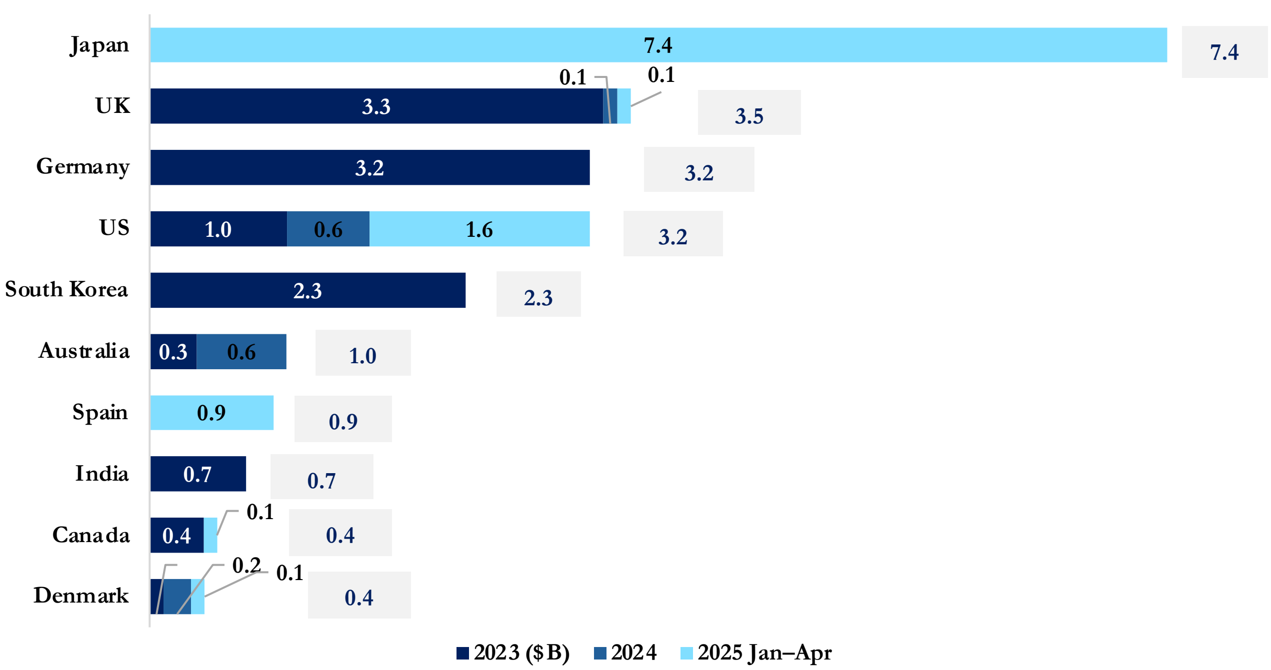
Through this initiative, Maharashtra aims to strengthen its academic and research ecosystem in quantum technologies and support the development of skilled human resources.

01 Background and Rationale

1.1 Global Emergence of Quantum Technologies

Quantum technologies are emerging globally, and the world is entering the second quantum revolution driven by advances in quantum computing, quantum communication, and quantum sensing. Recognising the transformative potential of these technologies, the United Nations has declared 2025 as the International Year of Quantum Science and Technology. Rapid technological advances and increasing investments indicate that quantum technologies are expected to play a major role in shaping future economic and technological competitiveness. The fourth annual Quantum Technology Monitor report, published by McKinsey, highlights that accelerating innovation and investment could propel the global quantum technology market to nearly $100 billion in the coming decade. The three core pillars of quantum technologies-quantum computing, quantum communication, and quantum sensing- are expected to drive significant technological and economic impact across multiple sectors. Advances in quantum computing are expected to accelerate domains such as drug discovery and advanced materials development, while also disrupting widely used cryptographic protocols such as public key encryption, creating the need for post-quantum cryptography

Chart 1.1: Quantum Investment (in $ Bn) across countries



Recognising the strategic importance of this emerging field, governments worldwide have begun to invest significantly in quantum technologies and to build national capabilities. Global public investments in quantum technologies reached nearly $10 billion in 2025, with countries such as Japan leading the way, while India is among the top 10 countries investing in quantum technology development. In India, several states, such as Karnataka and Telangana, have also launched initiatives to build ecosystems for research, industry collaboration, and skill development in quantum technologies.

Even before quantum technologies are widely available, governments are investing in developing research-ready manpower and preparing the workforce for the future quantum economy. The transition towards post-quantum cryptography and advanced quantum computing capabilities is expected to have significant implications for sectors such as finance, banking, defence, and pharmaceuticals. Given Maharashtra's strong presence in these sectors, building institutional capability and skilled manpower in quantum technologies is of strategic importance for the state.

In this context, a meeting was held on June 17, 2025, under the chairmanship of the Hon'ble Minister (Higher and Technical Education), followed by a review meeting on June 21, 2025, to initiate actions to build capacity in quantum technologies in Maharashtra. Subsequently, the Directorate of Technical Education requested IISER Pune, DBATU Lonere, COEP Technological University Pune, and VJTI Mumbai to submit a proposal outlining a phase-wise implementation strategy for faculty development, computing infrastructure, and laboratory facilities.

This proposal presents a hub-and-spoke model led by the I-Hub Quantum Technology Foundation at IISER Pune to build quantum technology teaching and research capabilities across selected engineering institutions in Maharashtra. The initiative aims to strengthen faculty capability, support technology development, and create a strong pool of talent for employment, research, and entrepreneurship in quantum technologies.

1.2 National Policy Context

The National Quantum Mission (NQM), approved by the Union Cabinet in April 2023, is India's flagship initiative to advance quantum technologies. With a budget allocation of ₹6,003.65 crore (approx. $730 million) for 2023-2031, the mission aims to establish India as a global leader in quantum computing, communications, sensing, and materials. Key objectives of NQM include:

- Developing intermediate-scale quantum computers (50-1000 physical qubits) by 2031.
- Establishing quantum communication networks spanning 2,000+ km.
- Advancing quantum sensing for precision navigation, imaging, and timing.

The NQM has established four thematic hubs (T-Hubs) at leading research institutions for quantum research and development. Department of Science & Technology (DST) and the Ministry of Electronics & Information Technology (MeitY) oversee implementation, in collaboration with the mission coordination cell established at IIT-Kanpur.

Regulatory frameworks for quantum communications and cryptography are also evolving in India. Institutions such as the Telecom Regulatory Authority of India (TRAI), the National Security Council Secretariat (NSCS), and the Reserve Bank of India (RBI) are addressing the implications of quantum technologies for secure communications, cybersecurity, and financial infrastructure. In parallel, initiatives led by MeitY and the Defence Research and Development Organisation (DRDO) are supporting the development of quantum-safe communication technologies and quantum key distribution systems.

Policies related to cybersecurity, intellectual property, and export controls are also adapting to developments in quantum technologies. For example, the National Cyber Security Policy emphasises transitioning to quantum-resistant encryption, while the Information Technology Act mandates compliance with cryptographic standards for protecting critical infrastructure.

India also has a growing ecosystem of academic institutions, research laboratories, and industry players engaged in quantum technology development. Government-supported initiatives such as the Quantum-Enabled Science & Technology (QuEST) programme and projects under the National Mission on Interdisciplinary Cyber-Physical Systems have supported research collaborations across institutions, including IISER Pune and TIFR Mumbai. IIT Bombay has also been designated as the national hub for quantum sensing under the National Quantum Mission.

Industry participation is also increasing, with companies such as Tata Consultancy Services, Infosys, Persistent Systems, Tech Mahindra, and Wipro developing research capabilities in quantum computing.

NITI Aayog has highlighted that India's quantum security strategy must integrate technology monitoring, research flexibility, supply chain security, global partnerships, and domestic innovation to ensure resilience in the emerging quantum era.

1.3 Maharashtra's Strategic Opportunity and Proposed MQM

In alignment with India's National Quantum Mission (NQM) launched in 2023, the Government of Maharashtra (GoM) aims to position the state as a hub for quantum innovation, talent development, and technology leadership.

The Information Technology Department, Government of Maharashtra, is also in the process of formulating a dedicated Quantum Technology Policy for the state to further support research, innovation, and ecosystem development in this emerging field.

Maharashtra already hosts a number of academic institutions, research laboratories, and industry sectors that can benefit from advances in quantum technologies. Leading institutions such as IISER Pune, IIT Bombay, ICT Mumbai, C-DAC Pune, TIFR Mumbai, and the National Chemical Laboratory contribute significantly to the state's scientific research ecosystem. In addition, organisations such as the Maharashtra Remote Sensing Application Centre and the Regional Remote Sensing Application Centre (ISRO) at Nagpur are likely to benefit from advances in quantum computing and quantum sensing for processing large volumes of geospatial data. Maharashtra is also a major hub for defence manufacturing and advanced technology industries, creating opportunities to apply quantum technologies across sectors such as defence, computing, materials science, and pharmaceuticals.

To support this objective, the state proposes a set of initiatives to build capacity in quantum technologies and strengthen the research and innovation ecosystem.

- **Building Quantum Capacity through Education and Training:**

  Through a "Quantum Computing Initiative for Maharashtra", faculty across state universities and technical institutions will receive specialised training in quantum technologies. The initiative aims to strengthen academic capability, integrate quantum science into higher education, and develop a skilled workforce aligned with emerging industry needs.

- **Fostering a Quantum Technology Ecosystem:**

  The Government of Maharashtra proposes to establish quantum technology centres in collaboration with institutions such as Dr. Babasaheb Ambedkar Technological University (Lonere), VNIT Nagpur, VJTI Mumbai, and COEP Technological University Pune under the leadership of the Innovation Hub Quantum Technology Foundation at IISER Pune. These centres will focus on building research capabilities in quantum computing and communication while also supporting startup incubation and industry collaboration.

1.4 Lessons from Previous Capacity Building Initiatives in Maharashtra

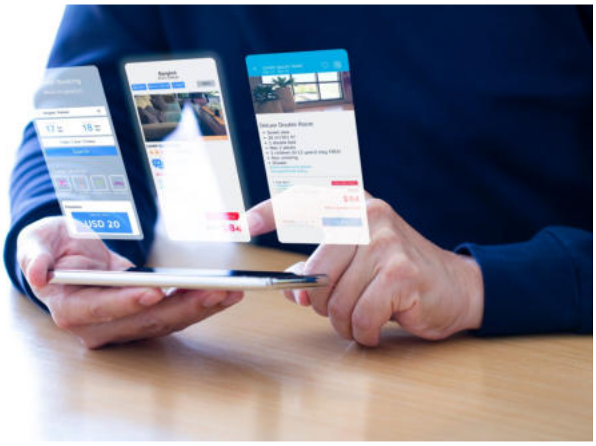
Over the past two decades (2000-2025), Maharashtra's premier technical institutes, including VNIT, COEP, DBATU, and VJTI, have participated in several government initiatives to strengthen technical education. Programs such as the World Bank-funded Technical Education Quality Improvement Programme (TEQIP) and the Pandit Madan Mohan Malaviya National Mission on Teachers' Training (PMMMNMTT) supported faculty development and laboratory infrastructure across institutions.

However, a review of these initiatives highlights certain limitations:

- The primary objective of these efforts was to produce employable graduates for the global IT industry and support student progression to advanced academic programs.
- Faculty capacity-building efforts focused largely on improving academic qualifications such as M.Tech. and PhD programs, with limited exposure to emerging deep technologies.
- Short-term faculty development programs were often fragmented and focused on soft skills or academic processes without integration into broader research or innovation ecosystems.
- Laboratory infrastructure investments were largely confined to undergraduate teaching labs, with limited emphasis on research-oriented or next-generation technology platforms.

Recent initiatives in states such as Andhra Pradesh and Karnataka provide useful lessons for developing quantum technology capabilities at the state level. For instance, Andhra Pradesh has launched the Amaravati Quantum Valley initiative to build an integrated ecosystem for quantum technologies through skilling programs, university collaborations, and industry partnerships. Similarly, Karnataka has supported the development of quantum research infrastructure and collaborative research initiatives through leading institutions such as IISc. These initiatives highlight the importance of early investment in talent development, shared research infrastructure, and strong academia–industry collaboration, which are reflected in the proposed capacity-building approach for quantum technologies in Maharashtra.

While these initiatives strengthened the technical education ecosystem, they were not designed to prepare institutions for emerging technologies such as quantum computing. This highlights the need for a more coordinated approach that strengthens faculty capability, develops research-oriented infrastructure, and enables institutions to participate in emerging technology ecosystems.



02 Scope, Vision and Objectives

This project scope is to build a strong foundation in quantum technology using a hub-and-spoke model. I-Hub QTF IISER Pune will serve as the main hub, while VNIT Nagpur, DBATU Lonere, COEP Technological University Pune, and VJTI Mumbai will act as spokes. The project will focus on faculty development, adding quantum topics to the curriculum, creating shared and local teaching and research facilities, and setting up the systems needed to gradually develop quantum technology capabilities.

2.1 Vision

The proposal envisions Maharashtra emerging as a leading state in quantum science and technology by developing future-ready human capital and strengthening institutional capability within its technical education ecosystem. By building a quantum-ready workforce, the initiative aims to support technological innovation, economic growth, and high-value employment opportunities in emerging quantum technology domains.

Building on the strengths developed through earlier initiatives such as the Technical Education Quality Improvement Programme (TEQIP) and the Pandit Madan Mohan Malaviya National Mission on Teachers and Teaching (PMMMNMTT), the mission seeks to strengthen faculty capability, develop teaching and research infrastructure, and promote applied research and innovation in quantum technologies.

2.2 Objectives

The initiative will pursue the following strategic objectives:

- **Develop a Quantum-Ready Faculty Ecosystem across the State**

  Build faculty capability in quantum technologies across participating institutions through structured training programmes and academic engagement.

- **Integrate Modular and Multi-level Quantum Technology Courses across State Institutions**

  Introduce quantum technology courses and specialisation tracks within undergraduate and postgraduate programmes.

- **Create Shared and Local Quantum Infrastructure for Teaching and Research**

  Establish shared and institution-level infrastructure to support teaching, training, and research activities in quantum technologies.

In the longer term, the initiative aims to support the development of a broader quantum technology ecosystem in Maharashtra through the following outcomes:

- **Prepare a Skilled Quantum Workforce for Research and Industry Roles**

  Support the development of trained students capable of contributing to research and industry applications in quantum technologies.

- **Enable Quantum-Focused Innovation and Entrepreneurship**

  Encourage innovation activities and entrepreneurship in quantum technologies within participating institutions.

- **Strengthen Collaborative Research Networks and Intellectual Property Generation**

  Promote collaborative research activities and support the generation of scientific publications and intellectual property in quantum technologies.

- **Build Strong Academia-Industry-Government Linkages**

  Encourage collaboration between academic institutions, industry partners, and government stakeholders in quantum technologies.

- **Establish Governance, Monitoring, and Sustainability Mechanisms**

  Develop institutional mechanisms for effective programme governance, monitoring, and long-term sustainability.

2.3 Future Expansion: Phase 2-Quantum Research Parks

An important element in training an employment-ready workforce in the state is close association with the deep-technology industrial ecosystem. In Phase 2 of the program, it is proposed to establish Quantum Research Parks. These Research Parks will function as nodal points for industry-academia collaboration in the state. The Quantum Research Parks will receive funding to set up shared facilities for fabrication, testing, and validation of quantum hardware. Such shared facilities provide an economically efficient means of supporting a broad range of critical infrastructure required for the state's start-up ecosystem.

These Research Parks will be set up in Mumbai, Pune, and Nagpur. The Quantum Research Park in Mumbai will be supported with IIT Bombay as the hub and will focus on quantum sensing and communication.

The Quantum Research Park in Pune will be supported with I-Hub QTF as the hub, with a focus on quantum computing and enabling technologies. A third, smaller Quantum Research Park will be set up in Nagpur to support logistics-based research and industrial collaboration, in alignment with Nagpur being the logistics hub under the Maharashtra State Logistics Policy (2024).

Quantum Research Parks will form a key source of industrial experience and training for the academic workforce in the state through industry-led internships.

03 Implementation Model (Hub-Spoke) and Stakeholder Roles

The proposed Maharashtra Quantum Technology Mission is designed as an inclusive, state-wide capacity-building initiative, aligned closely with India's National Quantum Mission and the hub-and-spoke model of collaborative development supported by the Department of Science and Technology (DST). The mission operates through a consortium of five institutions under a unified programme structure, covering the four major geographic regions of Maharashtra Mumbai, Konkan, Pune, and Vidarbha, with strategic oversight provided by the Department of Higher and Technical Education (H&TE), Government of Maharashtra.

Initially, four technical institutes from the state, namely VJTI, DBATU, COEP, and VNIT, will serve as spokes of the mission, with I-Hub QTF at IISER Pune as the hub. The Department of Higher and Technical Education will oversee the program's progress.

Table 3.1: Implementation Model at Glance

Institution	Role	Thematic Focus	Reporting To
I-Hub QTF, IISER Pune	HUB	Programme management; all four QT pillars; simulation hub; FDP delivery	DTE / Mission Steering Committee
COEP Technological University, Pune	SPOKE	Photonic quantum computing; HPC-quantum hybrid simulation	I-Hub QTF / DTE
DBATU, Lonere	SPOKE	Quantum algorithms; quantum-inspired optimisation; affiliated-college outreach	I-Hub QTF / DTE
VJTI, Mumbai	SPOKE	Photonic QC; trapped-ion hardware demonstrator; quantum sensing	I-Hub QTF / DTE
VNIT, Nagpur	SPOKE	Quantum-hybrid GPU computing; NISQ simulation; quantum ML	I-Hub QTF / DTE
DTE, Maharashtra	OVERSIGHT	Policy direction; fund release; milestone review; affiliated-college integration	Dept. of Higher and Technical Education, Govt. of Maharashtra

3.1 Role of I-Hub Quantum Technology Foundation, IISER Pune - Hub

- Designs, schedules, and hosts all Faculty Development Programmes for faculty nominated by the four spoke institutions, combining residential training at IISER Pune with structured online learning through a shared Learning Management System.
- Establishes and operates the centralised quantum simulation and cloud-access infrastructure, providing all consortium institutions and their students with access to simulation environments and real quantum hardware through cloud platforms. Students will have access to hands-on training through the quantum teaching laboratories set up at I-Hub QTF.
- Facilitates student internship placements at national research laboratories and quantum industry partners, enabling the development of industry-ready manpower.
- Supports pre-incubation of faculty and student quantum ventures through its existing startup ecosystem linked to the NMiCPS mission.
- Leads joint curriculum development across the consortium, ensuring alignment with NEP 2020, AICTE frameworks, and NQM competency standards.
- Submits periodic progress reports to the Department of H&TE and chairs the Mission Steering Committee.
- Reach out to industry partners such as Tech Mahindra, Persistent Systems, NXP, TCS, JP Morgan, and Accenture to explore collaboration in course delivery, guest lectures, industry projects, and internships under the quantum technology programs.

3.2 Role of the Four Spoke Institutions - VJTI Mumbai, DBATU Lonere, COEP Pune, and VNIT Nagpur

- Nominate faculty for training programmes hosted at I-Hub QTF and deploy trained faculty to independently deliver UG courses in Quantum Technology from AY 2026-27 and M.Tech courses from AY 2027-28.
- Establish Centres of Excellence in Quantum Technology at their respective campuses, along with Quantum teaching labs with locally accessible quantum optics teaching equipment, GPU-based simulation facilities, and cloud quantum computing access - ensuring students engage with quantum technologies without needing to travel outside their institution.
- Conduct Faculty Development Programmes for faculty at affiliated and regional colleges, extending the mission's reach beyond the four spoke campuses.
- Support student projects, hackathons, and innovation activities, with quantum incubation cells at each spoke linked to I-Hub QTF's startup ecosystem. For examples- I-Hub can provide industry relevant problem statements for innovation
- Contribute complementary thematic capabilities to the consortium - photonic quantum computing at COEP and VJTI; quantum algorithms and optimisation at DBATU; and quantum-hybrid GPU computing at VNIT ensuring the consortium develops depth across all four pillars of quantum technology without duplication.

3.3 Role of Department of Higher and Technical Education - Oversight

- Issues the Government Resolution authorising programme execution and milestone-linked fund disbursement.
- Conducts periodic reviews of mission objectives and deliverables against defined milestones, with authority to withhold subsequent fund tranches pending milestone verification.
- Coordinates with AICTE for formal recognition of the QT Minor and M.Tech programme structures developed under this mission.
- Directs affiliated colleges to integrate quantum technology courses into their academic calendars as the train-the-trainer cascade from spoke institutions takes effect.
- Facilitates faculty nomination and time release from spoke institutions for participation in I-Hub QTF-hosted FDPs.
- Identifies future growth locations for quantum capacity building as the programme scales beyond its initial four spokes toward the Phase 2 Quantum Research Parks.

The mission will commence with the capacity building of faculty and the infrastructure development of partner institutions, followed by curriculum roll-out at the same. Both faculty capacity building and curriculum design will be supported by shared & local infrastructure

04 Strategic Objectives, Activities and Deliverables

4.1 Short Term Objectives

1 Develop a Quantum-Ready Faculty Ecosystem across the state

In the initial phase, I Hub will organise hybrid training for select faculty. The program will adopt a **Train-the-Trainer model** to build faculty capability in quantum technologies across participating institutions. Partner institutions will nominate 4-5 faculty members per institution to participate in a six-month hybrid training program coordinated by I-Hub QTF at IISER Pune, combining residential training with online lectures delivered by academic and industry experts.

The training will comprise **10 structured courses,** each consisting of **approximately 40 hours** of instruction, covering theoretical modules, programming exercises, and interaction with experts. Faculty will also undergo **quantum laboratory training through 10 laboratory sessions of 3 hours** each at the MS Quantum Technologies Lab at I-Hub QTF, along **with supervised hands-on sessions on quantum algorithms** using quantum simulators. The weekly hours per course are designed to be approximately twice the AICTE-recommended norms for students.

To build teaching capability, faculty from DBATU, VJTI, COEP and VNIT will each deliver two lectures to students in the MS Quantum Technologies program at IISER Pune. The program will be implemented in multiple cohorts, with a target of training approximately **120 faculty members** across participating institutions during the implementation period.

Detailed course structure and training modules are **provided in Annexure I.**

Activities

1. I-Hub QTF to develop 6-month-long faculty training modules in online as well as offline formats
2. I-Hub QTF to identify and contract faculty and advisors for courses.
3. DBATU, VJTI, COEP and VNIT to identify and nominate faculty for the training program

Key Deliverables:

1. Six-month hybrid faculty training module in online & offline format
2. Contracted pool of faculty & advisors for the courses
3. Institute-wise nominated faculty lists from DBATU, VJTI, COEP & VNIT
4. Completed 1st, 2nd, & 3rd faculty training cohort
5. Train 20 faculty from state institutes between June-December 2026, followed by 50 faculty each in January-June 2027 and June-December 2027.

2 Integrate Modular and Multi-level Quantum Technology courses across state institutions

The program will integrate quantum technology education into existing academic programs across participating institutions. This will include the introduction of quantum technology courses and specialisation tracks within B.Tech, M.Tech, advanced PG Diploma or elective MTech modules, aligned with AICTE guidelines.

The curriculum will combine foundational courses, laboratory training, and specialised electives covering key areas such as quantum computing, quantum communication, quantum sensing, and quantum materials. Interdisciplinary content spanning physics, computer science, and electrical engineering will ensure that students gain both theoretical knowledge and practical skills.

Curriculum development will be carried out collaboratively by faculty from participating institutions with support from I-Hub QTF, ensuring alignment with emerging developments in quantum technologies and national priorities under the National Quantum Mission.

For undergraduate minor programmes, quantum technology courses will be introduced progressively over the four-year B.Tech programme. The minor programme will include at least one course per semester, with each course comprising approximately 40 contact hours. In accordance with NEP 2020 guidelines, the minor specialisation will consist of 28 credits distributed across the four-year programme, combining foundational concepts, laboratory exposure, and advanced electives.

For postgraduate programmes, the teaching methodology will combine theoretical coursework with practical training. Approximately 75% of instruction will be delivered through classroom-based learning, while 25% will involve laboratory sessions and hands-on training using quantum simulators and experimental teaching setups. In addition, postgraduate students will undertake at least one semester of internship in an industry or research institution, culminating in a thesis or research project. The indicative course structure for the B.Tech Minor and M.Tech programs aligned with the AICTE model curriculum is provided in Appendix III.

The course curriculum for the B.Tech Minor and M.Tech programs in Quantum Technologies will broadly follow the AICTE Model Curriculum developed under the National Quantum Mission. The B.Tech minor will introduce foundational concepts in quantum computing, communication, sensing, and materials through interdisciplinary coursework and laboratory exposure, enabling engineering students to build basic competency in quantum technologies. The M.Tech program will build on this foundation through advanced coursework, specialised electives, laboratory training, and research-oriented learning to prepare students for roles in research, innovation, and industry applications in quantum technologies.

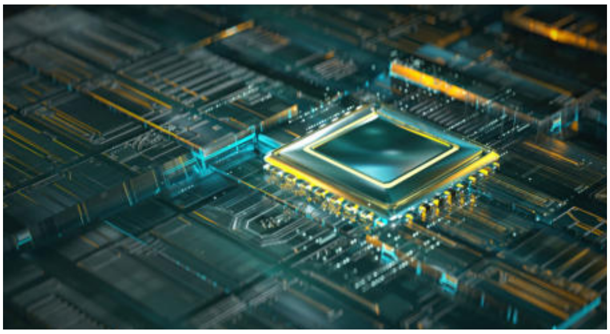
The developed curriculum will be rolled out across at least four partner institutions by the 2027 academic year, with a target enrolment of at least 320 students across undergraduate and postgraduate programs.

Activities

1. Develop and implement a curriculum for minor specialisation tracks within BTech and MTech programs to be offered in state institutes, in alignment with the AICTE norms.

2. Develop advanced PG Diploma or elective MTech modules in quantum technologies to be offered in state institutes in alignment with the AICTE norms.

3. Ensure curriculum aligns with AICTE and NQM standards, integrates lab-based and simulator-driven learning, and includes interdisciplinary content (physics, computer science, electrical engineering).



Key Deliverables:

1. Approved curriculum package for minor specialization tracks in B. Tech & M. Tech programs
2. Approved advanced PG Diploma or Elective M. Tech module in quantum technologies.
3. Roll out curriculum in at least 4 partner institutions by the 2027 academic year at undergraduate and master's level with enrolment of atleast 320 students.

Curriculum aligned with AICTE & NQM standards integrated to lab-based, simulator-driven, & interdisciplinary learning.

3 Create Shared and Local Quantum Infrastructure for Teaching and Research

To support teaching, training, and research activities in quantum technologies, the program will establish both centralised and distributed infrastructure across participating institutions.

A centralised simulation laboratory will be established at I-Hub QTF at IISER Pune, accessible across the participating institutions. This facility will provide access to quantum simulators and quantum computing systems via cloud platforms.

To complement the centralised simulation facility, experimental Quantum Teaching Laboratories will be established at the participating institutions-DBATU Lonere, VJTI Mumbai, COEP Technological University Pune, and VNIT Nagpur. These laboratories will support hands-on learning, faculty training, and student experimentation in quantum technologies.

Each institute-level laboratory will be equipped with quantum education kits, student simulation workstations, and local server-based simulators to support laboratory-based instruction and experimentation.

The central simulation facility at I-Hub QTF, IISER Pune, will support shared access for participating institutions and will include backend support and monitoring tools managed by I-Hub staff. The infrastructure will enable coordinated access to computing resources and support training, teaching, and research activities across the consortium.

Activities

1. Set up a centralised simulation lab at I Hub IISER Pune, accessible across the consortium, equipped with any of the following options:
   I. NVIDIA CUDA-Q-enabled simulation environments supported by cloud providers such as Yotta, E2E Networks, Tata Network
   II. Quantum System access via cloud, e.g. IBM, QPiAI
   III. Backend support and monitoring tools managed by I-Hub staff
2. Establish experimental Quantum Teaching Labs in four spoke institutes (DBATU, VJTI, COEP and VNIT), equipped with:
   I. Quantum education kits. A detailed breakdown of the equipment list for each institute is provided in Appendix II.
   II. 5+ student simulation workstations per site
   III. Local server-based simulators for offline instruction
3. Ensure full operational readiness of infrastructure, including access portals, training materials, and scheduling systems before 2027 academic year.

Key Deliverables:

1. Operational centralised simulation lab at I-Hub IISER, Pune

1. Operational experimental Quantum Teaching Labs in (DBATU, VJTI, COEP & VNIT).
2. Functional access portals, training materials & scheduling systems for infra. use.

4.2 Long-term Objectives

1 Prepare a Skilled Quantum Workforce for Research and Industry Roles

The following objectives outline the long-term outcomes of the mission, focusing on workforce development, research capability, innovation, and ecosystem building in quantum technologies.

Activities

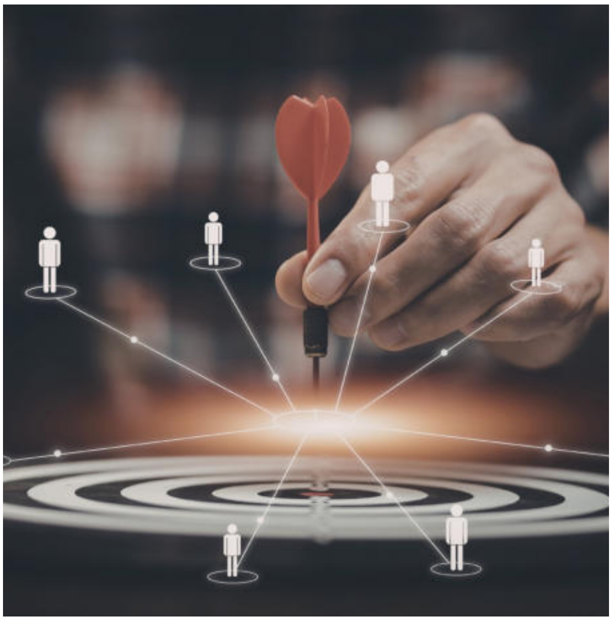
1. Train students in quantum computing and applications through a combination of coursework, laboratory experience, internships and guided projects.
2. Support internships across the state with a budgetary provision of 50 internships per year supported through a competitive process of open call.
3. Support final-year projects in real-world quantum applications (logistics, materials, cybersecurity, drug discovery) under faculty-industry mentorship.

Key Deliverables:

1. Trained 5000+ students in quantum computing and applications over 5 years.
2. Budgetary provisions established for the annual internship support mechanism.
3. Faculty-industry mentored final year projects.
4. Career tracking and reporting system for trained students.

Targets

Trained 5000+ students in quantum computing and applications over 5 years by expanding program to private institutions.



2 Enable Quantum-Focused Innovation and Entrepreneurship

Activities

1. Establish dedicated quantum incubation cells within each spoke institution, linked to the startup ecosystem at I-Hub Quantum Technology Foundation.

2. Support pre-incubation of 10-15 innovation projects per year, including:

    I. MVP development using quantum simulators

    II. Proof-of-concept trials with industry datasets

    III. Technical mentoring from domain experts

3. Provide seed funding (Rs. 5-10 lakh) and IP advisory services for faculty or student-led ventures, with a target of incubating 50 startups by 2030.

Key Deliverables:

1. Dedicated quantum incubation cells in each spoke

2. Annual pre-incubation for 10-15 projects

3. Seed funding and IP advisory support mechanism for faculty & student-led ventures

Targets

Fifty startups incubated by 2030.

3 Strengthen Collaborative Research Networks and IP Generation

Activities

1. Launch collaborative research clusters across the hub and spokes, aligned with strategic quantum domains (e.g., post-quantum cryptography, quantum ML, quantum sensors).

2. Target publication of at least 100 peer-reviewed papers and 50 quantum patents over five years.

3. Encourage joint PhD/postdoctoral programs involving multiple institutions and industry partners, with funding from national missions and international collaborators.

4. Organise an annual Maharashtra Quantum Symposium to share research outcomes and showcase emerging talent.

Key Deliverables:

1. Launched collaborative research clusters aligned with strategic quantum domains across the hub, & all spokes

2. Peer-reviewed & patents in targeted quantum areas in 5 years

3. The Annual Maharashtra Quantum Symposium is being organised.

Targets

1. Publish 100 peer-reviewed publications and 50 quantum patents in 5 years.

2. Organise Maharashtra Quantum Symposium annually

4 Build Strong Academia-Industry-Government Linkages

Activities

1. Sign MoUs with national and global quantum-focused companies, national labs, and strategic partners.
2. Co-design industry-driven coursework, internships, and research use cases in areas such as finance, materials, logistics, and pharmaceuticals.
3. Facilitate student and faculty placements in industry internships or contract research programs through a centralised platform hosted at I-Hub.

Key Deliverables:

1. Atleast 10 MoUs signed with national and global quantum-focused companies, national labs, and strategic partners.
2. Industry-driven coursework & internships & research use cases produced
3. Centralised placement /internship facilitation platform hosted at I-Hub

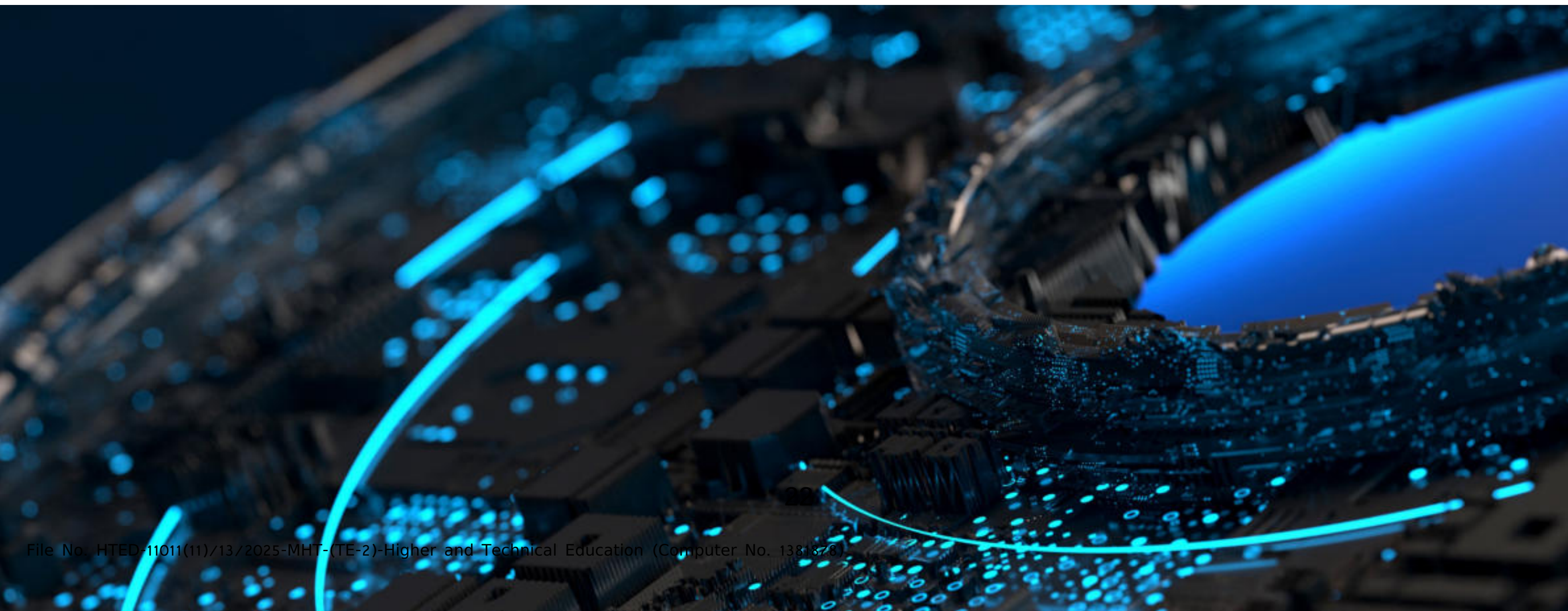
5 Establish Governance, Monitoring, and Sustainability Mechanisms

Activities

1. To ensure goal alignment and adaptive planning, create a Mission Steering Committee comprising representatives from IISER Pune, spoke institutes, industry, and DTE.
2. Build a centralised monitoring dashboard for tracking:
   i. Faculty trained
   ii. Students enrolled
   iii. Labs functional
   iv. Research/publication outputs
   v. Startups incubated
3. Prepare a 5-year sustainability roadmap including:
   i. Fee-based programs
   ii. Corporate sponsorships
   iii. Research grants (NQM, DST, AICTE, EU H2020

Key Deliverables:

1. Created Mission Steering Committee
2. Centralised monitoring dashboard for program tracking
3. A 5-year sustainability roadmap established.



05 Detailed Timelines of Activities

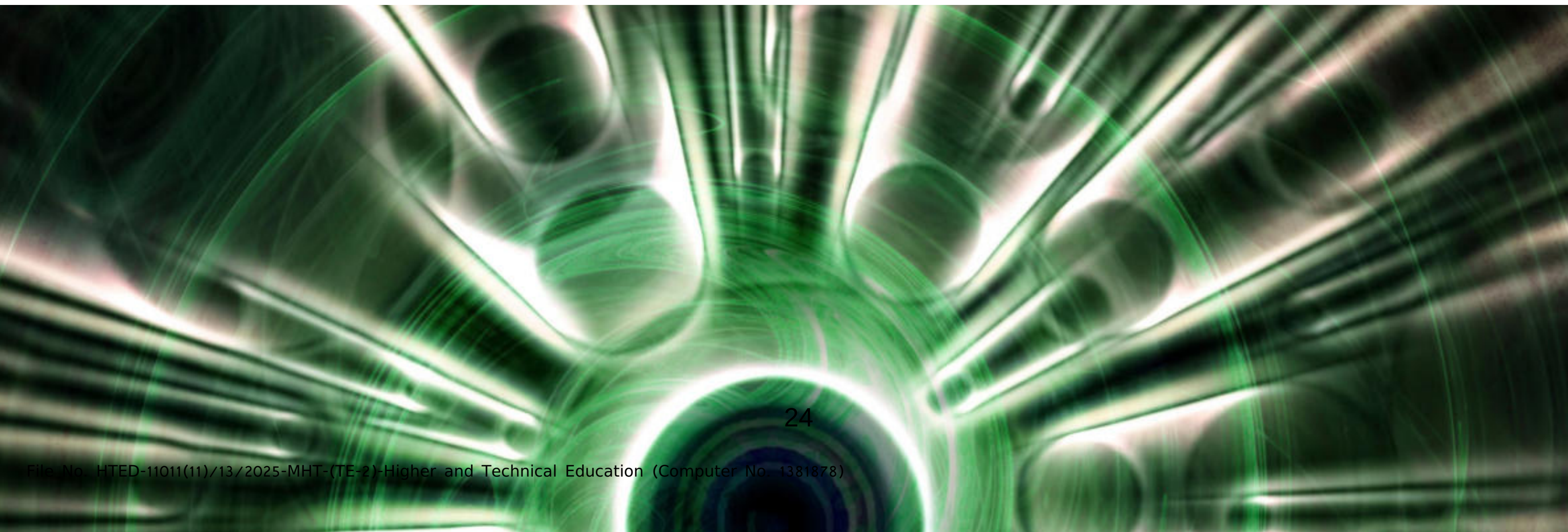
The program will be implemented in phases (Table 5.1) between June 2026 and December 2027, covering faculty training, curriculum rollout, and infrastructure development.

Table 5.1: Timelines of Activities

Objective	Activity	Responsible Institution(s)	Timeline*
Develop a Quantum-Ready Faculty Ecosystem across the State (Jun 2026-Dec 2027)	Develop 6-month faculty training modules (online and offline formats)	I-Hub QTF	July 2026
	Identify and contract trainers and advisors for courses	I-Hub QTF	
	Identify and nominate faculty for the training program	DBATU, VJTI, COEP, VNIT	
	Deliver faculty training program for 20 faculty members from state institutes (Online & offline Mode)	I-Hub QTF	July 2026-Dec 2026
	Deliver faculty training program for 50 faculty members Online & offline Mode)	I-Hub QTF	Jan 2027- June 2027
	Deliver faculty training program for 50 faculty members Online & offline Mode)	I-Hub QTF	June 2027- Dec 2027
Integrate Modular and Multi-Level Quantum Technology Courses across State Institutions	Develop curriculum for minor specialisation tracks within B.Tech and M.Tech programs aligned with AICTE norms	I-Hub QTF with partner institutes	June 2027
	Develop advanced PG Diploma or elective M.Tech modules in quantum technologies	I-Hub QTF with partner institutes	June 2027
	Ensure curriculum alignment with AICTE and NQM standards, including lab-based and simulator-driven learning	I-Hub QTF and partner institutes	June 2027
	Roll out curriculum across at least four partner institutions with enrolment of 320+ students	DBATU, VJTI, COEP, VNIT	June 2026- Dec 2027 (Academic Year)

Create Shared and Local Quantum Infrastructure for Teaching and Research	Establish centralised quantum simulation lab at I-Hub IISER Pune a) NVIDIA CUDA-Q-enabled simulation environments supported by cloud providers such as Yotta, E2E Networks, Tata Network b) Quantum System access via cloud e.g. IBM, QPiAI c) Backend support and monitoring tools managed by I-Hub staff	I-Hub QTF	July 2026
	Establish experimental quantum teaching labs at DBATU, VJTI, COEP, and VNIT a) Quantum education kits. Detailed break-up of the equipment list for each of the institutes is provided in Appendix A. b) 5+ student simulation workstations per site c) Local server-based simulators for offline instruction	Partner Institutes	July 2026-Dec 2026
	Install quantum education kits, simulation workstations, and local simulators	Partner Institutes	July 2026-Dec 2026
	Ensure full operational readiness of infrastructure, access portals, and training materials	I-Hub QTF and partner institutes	June 2027

*Subject to the release of funds by April 2026, the project will be implemented as per the proposed timeline.



The Gantt chart below illustrates the phased timeline for implementing the program's key activities between June 2026 and December 2027.

Table 5.1: Maharashtra Quantum Technology Mission — Activity Gantt Chart (Phase 1: Jul 2026 – Dec 2027)

			FY 2026-27												FY 2027-28					
Objective	Activity / Deliverable	Responsible Institution(s)	Jul 2026	Aug 2026	Sep 2026	Oct 2026	Nov 2026	Dec 2026	Jan 2027	Feb 2027	Mar 2027	Apr 2027	May 2027	Jun 2027	Jul 2027	Aug 2027	Sep 2027	Oct 2027	Nov 2027	Dec 2027
Develop a Quantum-Ready Faculty Ecosystem (Jun 2026 – Dec 2027)	Develop 6-month faculty training modules (online & offline formats)	I-Hub QTF	■	■																
	Identify and contract trainers and advisors for courses	I-Hub QTF	■	■																
	Identify and nominate faculty for the training program	DBATU, VJTI, COEP, VNIT	■	■	■															
	Deliver faculty training — 20 faculty members (online & offline)	I-Hub QTF	■	■	■	■	■	■												
	Deliver faculty training — 50 faculty members (online & offline)	I-Hub QTF							■	■	■	■	■	■						
	Deliver faculty training — 50 faculty members (online & offline)	I-Hub QTF												■	■	■	■	■	■	■
Integrate Modular & Multi-Level Quantum Technology Courses	Develop curriculum for minor specialisation tracks (B.Tech & M.Tech, AICTE-aligned)	I-Hub QTF + Partner Institutes							■	■	■	■	■	■						
	Develop advanced PG Diploma / elective M.Tech modules in QT	I-Hub QTF + Partner Institutes							■	■	■	■	■	■						
	Ensure curriculum alignment with AICTE and NQM standards (lab + simulator learning)	I-Hub QTF + Partner Institutes									■	■	■	■						
	Roll out curriculum at 4+ partner institutions — enrolment of 320+ students	DBATU, VJTI, COEP, VNIT													■	■				
Create Shared & Local Quantum Infrastructure for Teaching & Research	Establish centralised quantum simulation lab at I-Hub IISER Pune (NVIDIA CUDA-Q, Yotta/E2E/Tata Network cloud, IBM Q, QPiAI)	I-Hub QTF	■	■																
	Establish experimental quantum teaching labs at DBATU, VJTI, COEP, VNIT (Quantum education kits, 5+ student simulation workstations/site, local server simulators)	Partner Institutes	■	■	■	■	■	■												
	Install quantum education kits, simulation workstations, and local simulators	Partner Institutes	■	■	■	■	■	■												
	Ensure full operational readiness of infrastructure, access portals, and training materials	I-Hub QTF + Partner Institutes									■	■	■	■						

Legend:	
(dark red)	Faculty Development
(brown)	Curriculum Development
(dark navy)	Infrastructure Setup

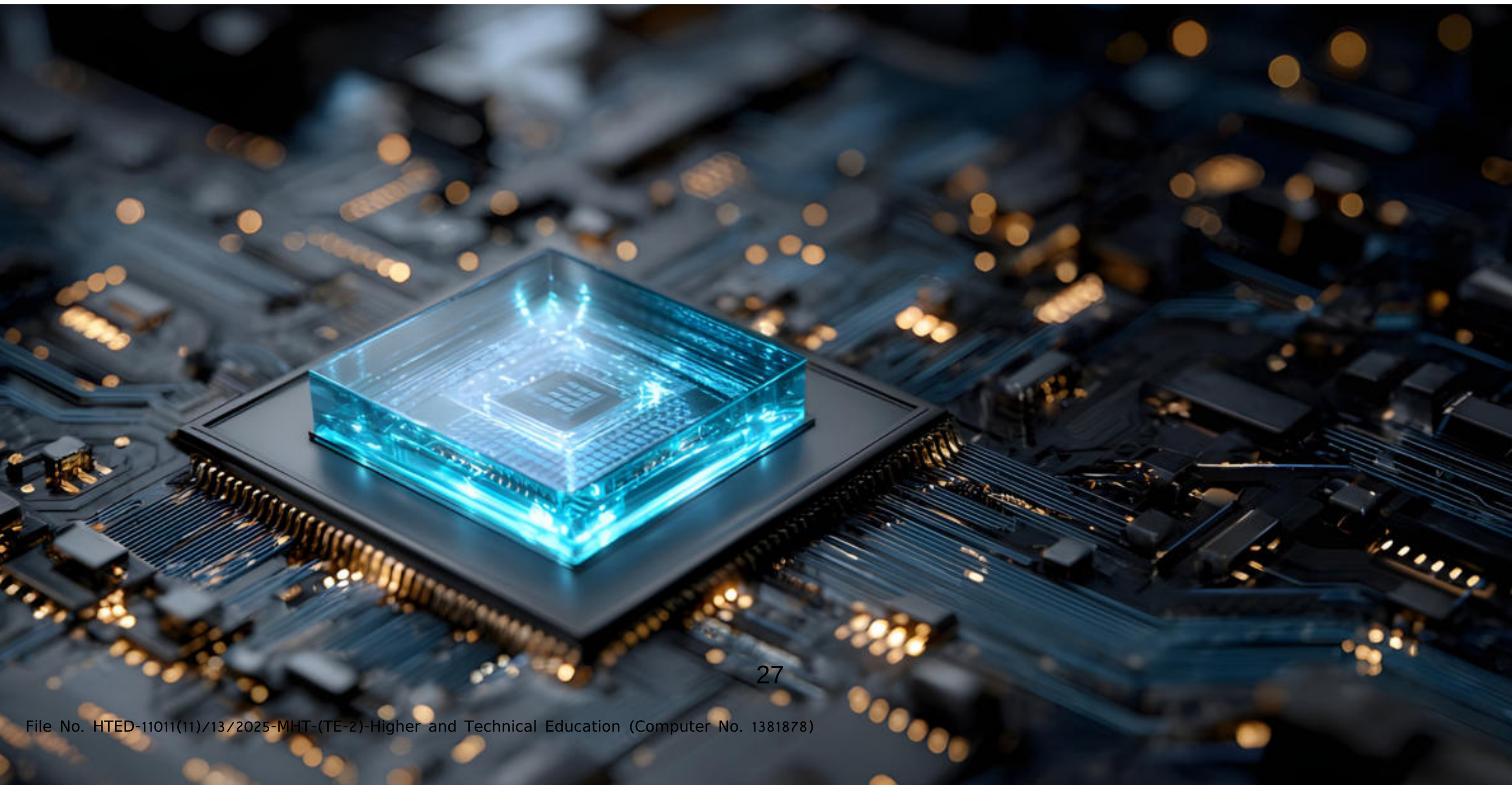
06 Expected Outcomes

The Phase 1 implementation of the Maharashtra Quantum Technology Mission is expected to generate measurable outcomes in faculty capacity building, academic programme development, infrastructure creation, and student participation across partner institutions.

Table 6.1: Year-wise Expected Outcomes of Phase 1

Outcome Area	Outcome Indicator	Year 1 (FY 2026–27)	Year 2 (FY 2027–28)
Faculty Capacity Building in Quantum Technologies	Faculty trained through structured hybrid training programme	45 faculty trained across participating institutions through two cohorts (Cohort 1: Jun-Dec 2026 - 20 faculty; Cohort 2: Jan-Jun 2027 - 25 faculty)	75 additional faculty trained through the second (Jan-Jun 2027 - 25 faculty) & third cohort (Jun-Dec 2027)
	Courses delivered under faculty training programme	15 courses fully delivered across training cohorts	15 courses fully delivered across training cohorts
	Instructional hours delivered under faculty training programme	600 instructional hours delivered (15 courses × 40 hours)	600 instructional hours delivered (15 courses × 40 hours)
	Quantum laboratory training	15 laboratory sessions (3 hours each) delivered per cohort	15 laboratory sessions (3 hours each) delivered per cohort
Integrate Modular and Multi-level Quantum Technology courses across state institutions	Quantum technology curriculum development and roll out	Curriculum for B.Tech Minor and advanced PG/M.Tech modules developed and approved in participating institutions	Quantum technology courses rolled out across at least 4 partner institutions beginning June 2027 academic session
	Student enrolment in quantum technology programmes	Initial student intake begins	~200 students enrolled in B.Tech Minor and ~120 students in advanced programmes
Quantum Teaching and Simulation Infrastructure	Centralised quantum simulation facility	Simulation infrastructure established at I-Hub QTF, IISER Pune	Shared access operational across consortium institutions
	Quantum teaching laboratories at partner institutions	Laboratories established at DBATU, VJTI, COEP and VNIT	Fully operational laboratories supporting teaching and student projects

Prepare a Skilled Quantum Workforce for Research and Industry Roles	Internship support mechanism for quantum training	Internship framework designed	50 internships supported across the state
Enable Quantum-Focused Innovation and Entrepreneurship	Quantum incubation ecosystem	Incubation framework established at I-Hub and spoke institutions	Quantum incubation cells operational across participating institutions
	Innovation and pre-incubation projects supported	Innovation calls and mentoring structure established	10–15 innovation projects supported
Strengthen Collaborative Research Networks and IP Generation	Collaborative research clusters across hub and spokes	Research clusters established	Collaborative research activities initiated
	Maharashtra Quantum Symposium	-	1 symposium organised
Build Strong Academia-Industry Government Linkages	Industry partnerships and MoUs	Industry outreach initiated	MoUs signed with industry/research partners
	Platform for internships and industry collaboration	Platform framework developed	Initiation of Platform development.



Long-Term Expected Outcomes

Over the longer term, the initiative is expected to contribute to the following outcomes:

1. 5000+ students trained in quantum computing and related technologies through coursework, laboratory training, internships, and research projects over five years.
2. Quantum innovation ecosystem strengthened, supporting 10-15 innovation projects annually and enabling the incubation of up to 50 startups by 2030.
3. Collaborative research capability enhanced, targeting 100 peer-reviewed publications and 50 patents within five years in key quantum technology domains.
4. Stronger academia-industry-government linkages, including at least 10 partnerships with national and global quantum technology organisations.
5. Sustained collaboration across the hub-and-spoke institutional network, supported through research activities, industry engagement, and knowledge-sharing platforms such as the Maharashtra Quantum Symposium.

4. A hub-and-spoke quantum ecosystem is established in Maharashtra.
5. Students gain structured pathways into quantum education and training.
6. A larger skilled quantum workforce begins to emerge for research and industry.
7. Applied research capacity in quantum technologies is strengthened.
8. Quantum innovation and entrepreneurship are stimulated within the state.
9. Academia, industry, and government linkages in quantum technologies become stronger.
10. A governance and monitoring system for sustained mission delivery is established.
11. Maharashtra's position as a leading state in quantum science and technology is strengthened.
12. Economic growth and high-end job creation in quantum technologies are enabled over time.

By establishing a Quantum Technology Capability, the Phase 1 of the project expects to achieve the following outcomes.

1. A quantum-ready faculty base is created across Maharashtra's technical institutions
2. Quantum technology curricula become institutionally embedded in partner institutes.
3. A functional state-wide quantum teaching and simulation infrastructure becomes operational.

07 Budget Estimate

The Maharashtra Quantum Technology Mission Phase 1 requires a total Government of Maharashtra grant of Rs. 20 Crore (Table 7.1) over two financial years, disbursed across five participating institutions. This investment funds two parallel streams of activity: durable quantum teaching infrastructure at the four spoke institutions, and a centralised programme delivery, training, and cloud-computing hub at I-Hub Quantum Technology Foundation, IISER Pune.

The funding is structured to reflect the natural sequencing of the programme. FY 2026-27 concentrates on human capital - faculty training delivery, foundational lab equipment, and the launch of UG minor courses. FY 2027-28 builds on that foundation with heavier infrastructure procurement (GPU computing clusters, advanced research equipment) that can only be deployed productively once trained faculty are in place to use it.

The table below provides a consolidated view by institution, financial year, and expenditure type.

Table 7.1: Consolidated Budget Phase 1

Institution	FY 26-27		FY 27-28		Total (Rs. Cr)
	CAPEX (Rs. Cr)	OPEX (Rs. Cr)	CAPEX (Rs. Cr)	OPEX (Rs. Cr)	
I-Hub QTF, IISER Pune (HUB)	0.5	4.58	-	4.42	9.50
COEP Technological University, Pune	0.80	0.20	1.25	0.25	2.50
DBATU, Lonere	0.50	0.17	1.55	0.28	2.50
VJTI, Mumbai	1.5	0.25	0.5	0.25	2.50
VNIT, Nagpur	1.76	0.37	0.29	0.58	3.00
PHASE 1 TOTAL	5.06	5.57	3.59	5.78	20.00

7.1 Year-wise Government Outlay

FY 2026-27 – Approximately Rs. 10.63 Crore (Table 7.2)

In the first financial year, the priority is to get people trained and the programme operationally running. The dominant spend is at I-Hub QTF, which receives Rs. 5.08 Crore to stand up the centralised quantum simulation hub, contract expert faculty, launch the Learning Management System, and deliver the first cohort of residential Faculty Development Programmes to all four spoke institutions. Simultaneously, each spoke institution receives its Year 1 allocation to procure foundational quantum optics teaching equipment - the hands-on lab kits that form the backbone of the UG Minor laboratory curriculum - and begin delivering the minor programme from FY 2026-27.

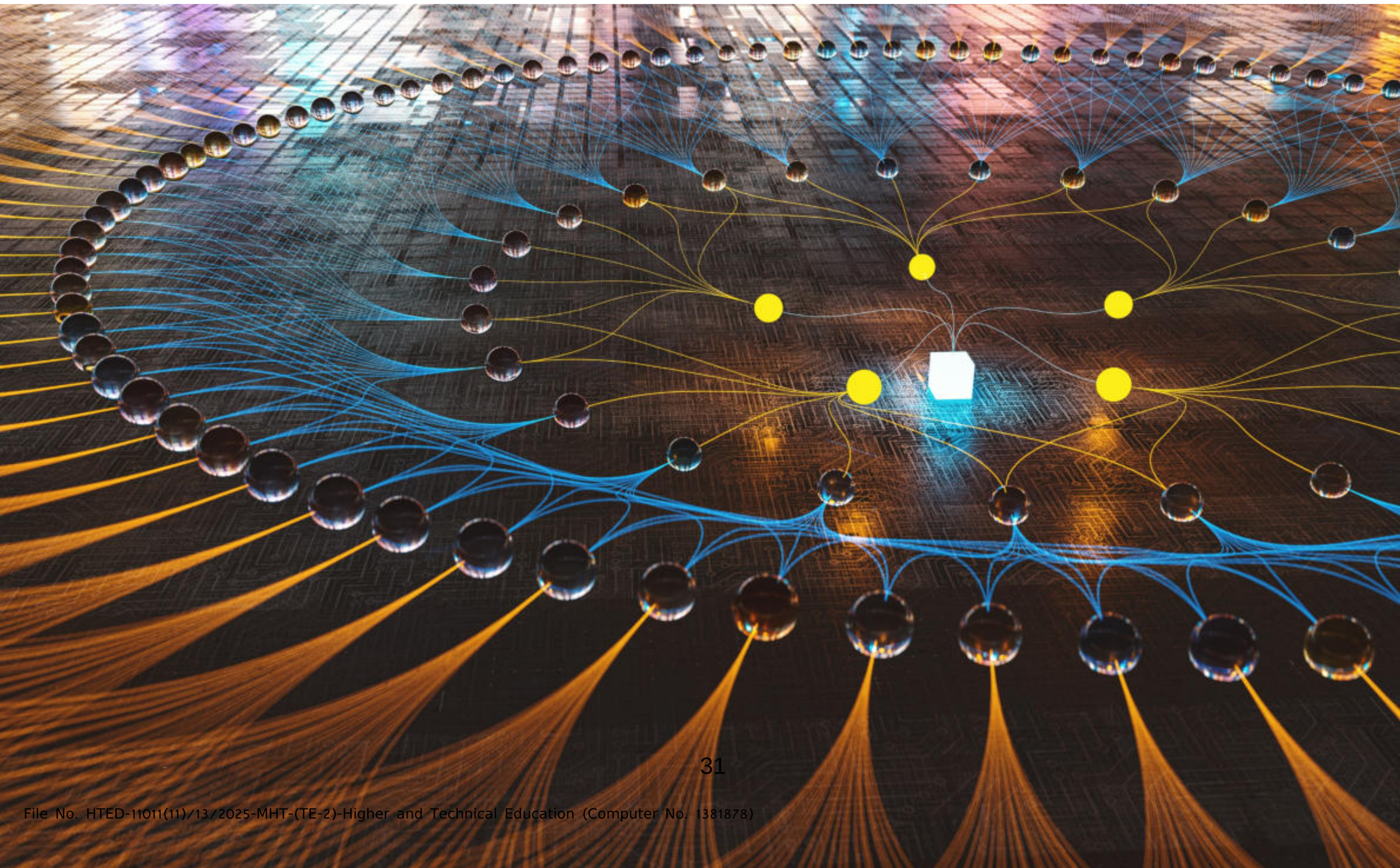
Table 7.2: Cumulative Budget FY 2026-27

Institution	FY 2026-27 Requirement (Rs. Crore)	Primary Use
I-Hub QTF, IISER Pune	5.08	Simulation hub setup; FDP delivery; cloud access; expert honoraria
COEP Technological University, Pune	1.00	Foundational lab setup; FDP for affiliated colleges; cloud subscriptions
DBATU, Lonere	0.67	Quantum optics and cryptography demo kits; FDPs; cloud subscriptions
VJTI, Mumbai	1.75	Photonic lab and trapped-ion demonstrator procurement
VNIT, Nagpur	2.13	GPU cluster; quantum optics kits; FDPs for regional colleges
TOTAL FY 2026-27	10.63 Cr	-

FY 2027-28 – Approximately Rs. 9.37 Crore (Table 7.3)

The second year is infrastructure heavy. Faculty trained in Year 1 are now equipped to supervise student projects and conduct research - making GPU computing clusters, advanced optimisation hardware, and expanded cloud access immediately productive investments rather than aspirational ones. I-Hub QTF continues programme delivery operations, cloud access, and now adds student internship support. Spoke institutions complete their CoE-QT buildout and scale FDP outreach to affiliated colleges.

Table 7.3: Cumulative Budget FY 2027-28		
Institution	FY 2027-28 Requirement (Rs. Crore)	Continued FDP delivery; cloud access; internship support; overheads
I-Hub QTF, IISER Pune	4.42	HPC cluster + GPU nodes; expanded FDPs; cloud subscriptions
COEP Technological University, Pune	1.50	GPU cluster (3× A100/H100); Coherent Ising Machine; expanded FDPs
DBATU, Lonere	1.83	Year 2 activities
VJTI, Mumbai	0.75	Cryptography demo kit; Coherent Ising Machine; 10 regional FDPs
VNIT, Nagpur	0.87	Continued FDP delivery; cloud access; internship support; overheads
TOTAL FY 2027-28	9.37 Cr	-



7.2 Justification for Major Expenditure Items

The budget across all five institutions is built around four categories of expenditure. The justification for each, as submitted by the participating institutions, is summarised below.

1 Quantum Optics Teaching Equipment (Thorlabs Quantum Optics Kits, Quantum Eraser Demonstration Kits, and Quantum Cryptography Analogy Demonstration Kits - procured at DBATU, VJTI, and VNIT)

These experiments are essential precursors to quantum computing, enabling structured UG and PG laboratory courses, Faculty Development Programmes, and outreach activities. The photonic quantum optics kits set up experiments in superposition, interference, measurement back-action, and entanglement phenomena that significantly reduce learning barriers before students transition to more advanced quantum computing platforms. The Quantum Cryptography Analogy kit provides hands-on demonstration of quantum key distribution protocols, directly relevant to the communication and cryptography curriculum track.

2 High-Performance GPU Computing Infrastructure (NVIDIA A100/H100-class servers procured at COEP, DBATU, VJTI, and VNIT)

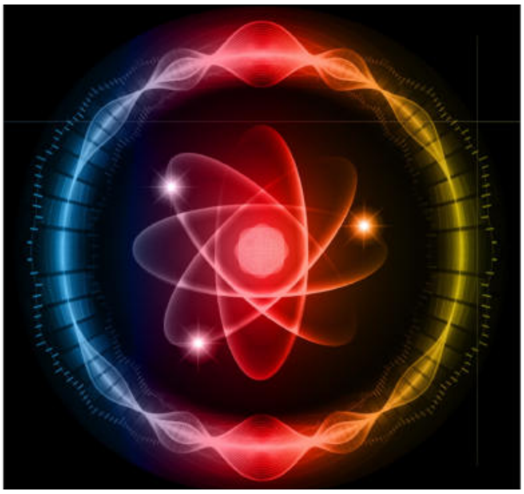
The NVIDIA GPU-based platform enables large-scale simulation of Noisy Intermediate-Scale Quantum (NISQ) systems and execution of hybrid algorithms such as VQE, QAOA, and quantum machine learning models. High-end GPUs are indispensable for tensor network contraction, state-vector simulation beyond 30-40 qubits, and real-time classical optimisation loops tightly coupled to quantum circuits workloads that standard computing infrastructure cannot support. This infrastructure ensures scalable access for teaching, research, and industry-relevant problem solving across the consortium.

3 Quantum Simulation and Cloud Access (NVIDIA CUDA-Q / cuQuantum, IBM Quantum Experience, D-Wave, QPiAI centralised at I-Hub QTF with per-spoke subscriptions)

Cloud quantum platform access enables hybrid execution on real quantum processing units and provides hands-on experience with NISQ systems for faculty and students across all five institutions. I-Hub QTF's simulation hub creates a shared sandbox environment in collaboration with NVIDIA, QPiAI, IBM, and Yotta supporting both teaching and the development of teaching materials. Per-spoke cloud subscriptions at IBM Quantum and D-Wave supplement this centralised access for independent faculty research and student project work at each institution.

4 Quantum-Inspired Optimisation Hardware (Time-Multiplexed Coherent Ising Machine, Quanfluence procured at DBATU and VNIT)

This system is procured to conduct research and development for quantum-inspired optimisation algorithms-a class of problems with direct applications in logistics, finance, and pharmaceuticals that are of strategic importance to Maharashtra. Quanfluence is an Indian manufacturer, and this procurement supports indigenous quantum hardware development in alignment with national policy..



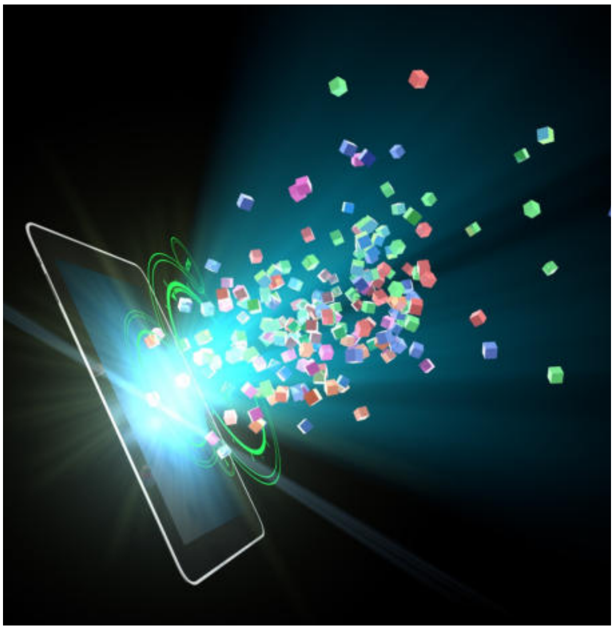
5 Training, Capacity Building, and Faculty Development Programmes

I-Hub QTF's training budget covers hosting faculty at IISER Pune, lab consumables, and honoraria for tutors and teaching assistants, as well as honoraria for expert instructors, travel and boarding costs, creation of online training materials, video recording, and Learning Management System service charges. Per-spoke FDP budgets are set at Rs. 5 Lakhs per one-week programme covering expert faculty costs, participant support, and lab materials consistent with prevailing rates for government-funded technical faculty development programmes.

For total spend of Rs. 20 Crore over two years, the Government of Maharashtra receives:

- **100+ faculty** across four state engineering institutions trained to independently deliver quantum technology courses - a permanent, durable human capital asset that does not depreciate.
- **4 Centres of Excellence in Quantum Technology** established at COEP, DBATU, VJTI, and VNIT - each with locally accessible quantum computing labs capable of supporting 100+ students per semester without dependence on any external institution.
- **A UG Minor in Quantum Technology** running at all four spoke institutions from AY 2026-27, reaching an estimated 500 students per year and 2,500+ students over five years building the pipeline for India's quantum workforce from Maharashtra.
- **An M.Tech in Quantum Technology** commencing AY 2027-28 across the consortium, creating a postgraduate pathway that does not currently exist in any state-funded engineering university in Maharashtra.
- **Access to real quantum computers -** IBM Quantum System Two (133 qubits), QPiAI, and D-Wave systems - for all 5,000+ students and 100+ faculty in the programme, centralised through I-Hub QTF at a fraction of the cost of physical hardware ownership.
- **Faculty Development Programmes** delivered to affiliated engineering colleges across the state, seeding quantum literacy into DBATU's network of colleges and VNIT's Vidarbha regional institutions.
- **A foundation for Phase 2** - the Quantum Research Parks at Mumbai, Pune, and Nagpur - with trained faculty, functioning labs, and an active student research community already in place to populate them.

The cost per trained faculty member, at approximately Rs. 20 Lakh over two years including all infrastructure and programme costs, compares favourably with the Rs. 15-25 Lakh typically spent per faculty under TEQIP for domain-agnostic training with no research infrastructure component.



7.3 Bill of Quantities for Hardware, Software, Cloud & Manpower & Training

Quantum technology is a domain deeply rooted in experimental learning. The employment opportunities of the future will demand skills spanning both computational and experimental expertise a reality reflected in global workforce surveys that consistently highlight hands-on laboratory experience as among the most sought-after competencies in quantum job postings. With this in view, it is important to provide deep-rooted experimental experience to students of quantum technologies alongside access to simulation and cloud-based quantum computing platforms.

I-Hub QTF has taken the lead in setting up Quantum Teaching Labs at IISER Pune for students of its MS Quantum Technologies programme, providing a lab-based course with 3 credits focused on quantum technologies. Building on this foundation, each of the four spoke institutions COEP, DBATU, VJTI, and VNIT has prepared a detailed Bill of Quantities for the planned laboratory equipment, computing infrastructure, software, and cloud resources at their respective locations. The total Phase 1 budget of Rs. 20 Crore is distributed across four expenditure categories: Hardware (Rs. 8.80 Cr), Cloud Access (Rs. 6.25 Cr), Manpower & Training (Rs. 4.80 Cr), and Software (Rs. 0.15 Cr), as summarised in Table 7.4 below. The detailed line-item Bill of Quantities for each institution including technical specifications, quantities, unit costs, and CAPEX/OPEX classification is provided in Annexure IV.

Table 7.4: Budget Summary Category-wise (in Crores)

Partner Institutions	HARDWARE	SOFTWARE	CLOUD	MANPOWER & TRAINING	TOTAL
IISER	0.50	-	5.80	3.20	9.50
COEP	2.05	-	0.10	0.35	2.50
DBATU	2.00	0.05	0.15	0.30	2.50
VJTI	2.25	0.05	0.05	0.15	2.50
VNIT	2.00	0.05	0.15	0.80	3.00
Total	8.80	0.15	6.25	4.80	20.00

Source: From the Individual Quotations of Institutes.

7.4 Milestone-Linked Fund Release

Funds will be released in three tranches (Table 7.4) to ensure accountability and active programme management. No subsequent tranche is released without DTE verification of the preceding milestone.

Table 7.5: Milestone-Linked Fund Release

Tranche	Amount	Release Condition	Expected By
Tranche 1	50% of each institution's allocation	GR issued; MoU with I-Hub QTF signed; faculty nominees confirmed; lab space certified ready	Within 1 month of GR issuance
Tranche 2	30% of each institution's allocation	Winter FDP completed; equipment purchase orders placed; UG Minor curriculum approved by at least 2 spoke senates; LMS operational	End of FY 2026-27 (March 2027)
Tranche 3	Remaining 20%	Summer FDP completed; equipment installed and operational; UG Minor student enrolment data submitted; mid-term progress report accepted by DTE	Q2 of FY 2027-28 (October 2027)

Tranche releases are institution-independent - a delay at one spoke does not withhold funds from others that have met their milestones. I-Hub QTF's tranche schedule is linked to FDP delivery milestones rather than equipment procurement milestones, reflecting its role as programme host rather than infrastructure builder.

08 Sustainability Plan

8.1 Financial and Institutional Sustainability

Quantum technology is, by global consensus, still in its nascent stage. Commercial quantum computers capable of outperforming classical systems on practically relevant problems what researchers call "quantum advantage" are expected to emerge progressively through the late 2020s and into the 2030s. This is not a limitation unique to Maharashtra or India; it is the current state of the technology worldwide. It has a direct and important implication for how the Government of Maharashtra should think about the financial sustainability of this mission: the infrastructure and expertise being built today will require continued stewardship through a period when the technology is maturing, before the commercial and fee-based revenue streams that a mature quantum ecosystem would generate become available at scale.

The programme is designed with this reality in mind. Phase 1 lays the human and physical foundation. By the end of Phase 1, the costs of running the academic programmes - UG Minor courses, M.Tech coursework, and associated lab sessions - will progressively transition into the regular operating budgets of the participating institutions, supported by student programme fees and internal research grants. The quantum laboratories and simulation infrastructure established through this mission will continue to generate value through teaching, externally funded research projects from DST, MeitY, AICTE, and the National Quantum Mission, and industry-sponsored research collaborations in computing, defence, pharmaceuticals, and finance.

However, the Government of Maharashtra should plan with transparency: given the nature of quantum tech

However, the Government of Maharashtra should plan with transparency: **given the nature of quantum technology - its high infrastructure costs, the pace of hardware evolution requiring periodic upgrades, and the global investment race in which state-level inaction is itself a cost - some degree of continued government support is likely to be necessary through Phase 2.** Every major quantum programme globally - the EU Quantum Flagship, the US National Quantum Initiative, Japan's Moonshot programme - is structured around sustained multi-year government commitment precisely because the technology's maturation timeline does not align with a single budget cycle. Maharashtra's Rs. 20 Crore Phase 1 investment positions the state to be a credible participant in India's quantum future; sustaining that position beyond phase 1 will require continued partnership between government, academia, and industry.

Revenue Streams beyond the project period

Sustainability will be ensured through a combination of diversified funding sources and the integration of quantum technology programs into the regular academic ecosystem of participating institutes.

- **Programme Fees:** UG Minor and M.Tech programme fees from enrolled students, and fee-based short-term certification courses for working professionals in finance, IT, and defence sectors.
- **Industry and Private Sector Partnerships:** Sponsored research agreements, equipment co-funding, and internship partnership fees from companies with quantum computing interests in Maharashtra.

- **Competitive Research Grants:** Ongoing funding from DST, MeitY, AICTE, National Quantum Mission T-Hubs, and international collaborators as faculty research output matures.

- **Government Support:** Continued state government budgetary support for infrastructure maintenance, hardware upgrades, and programme operations - particularly for Phase 2 Quantum Research Park infrastructure is anticipated and should be planned for in the state's technology investment roadmap.

After the initial project period, the faculty training modules and academic curricula developed under the mission will be embedded into regular degree programs such as B.Tech minors, PG diplomas, and M.Tech specialisations offered by the partner institutions. The quantum laboratories and simulation infrastructure established through the project will continue to be utilised for teaching, research, and industry collaboration.

Participating institutes will progressively support operational expenses through internal budgets, student program fees, and externally funded research projects from agencies such as DST, MeitY, AICTE, and the National Quantum Mission.

In addition, partnerships with industry players in computing, defence, pharmaceuticals, and finance will be explored for sponsored research, internships, and technology development.

Over time, the ecosystem created by this mission is expected to generate intellectual property, startup activity, and consultancy opportunities, further strengthening financial sustainability.

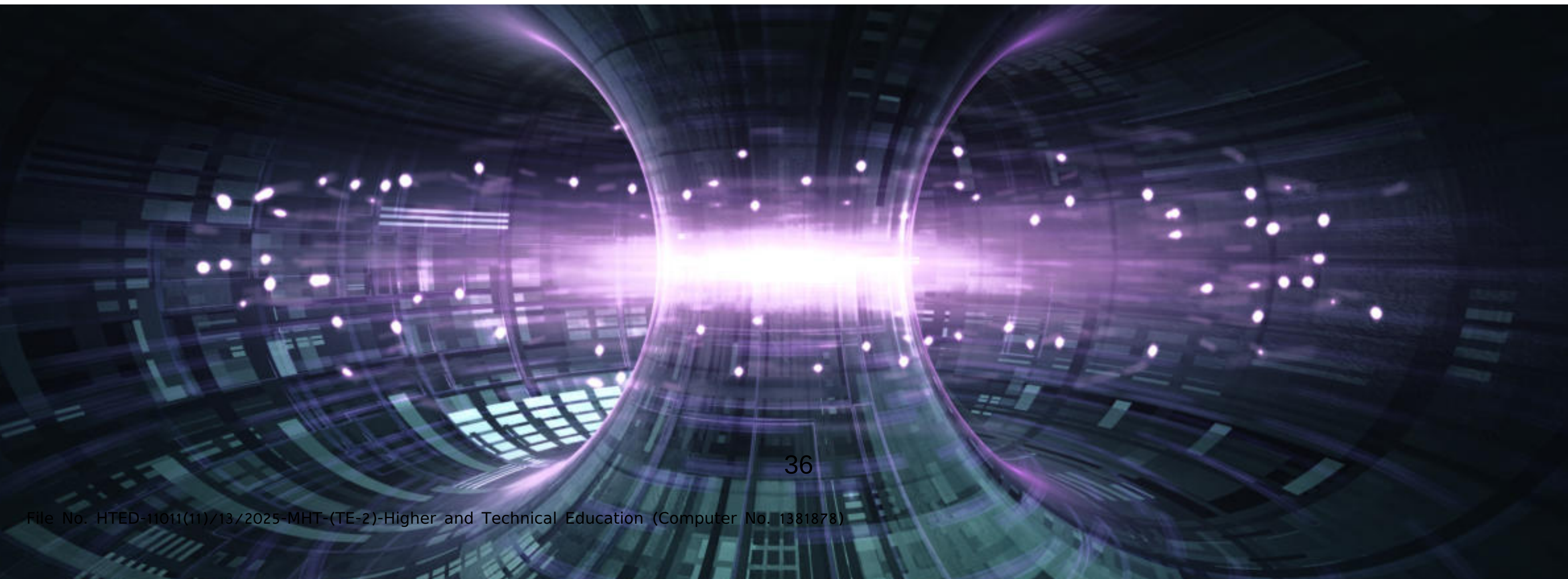
8.2 Faculty Retention Mechanism

Retention of trained faculty is critical for sustaining quantum technology capability within the participating institutions. The program proposes several mechanisms to ensure long-term engagement and motivation of trained faculty members.

Faculty who completes the advanced training program will be designated as Quantum Technology Coordinators within their respective institutes and will lead curriculum development, laboratory activities, and student research projects. Institutes will be encouraged to recognise these roles through academic incentives such as eligibility for internal research grants and priority support for conference participation and international collaborations.

Trained faculty will also be encouraged to participate in multi-institutional projects, industry collaborations, and national mission programs. Opportunities to supervise postgraduate students, supervise doctoral theses, guide innovation projects, and participate in startup incubation initiatives will further strengthen their academic engagement.

In addition, periodic advanced training programs, visiting scholar opportunities, and joint research proposals will ensure continued professional growth, thereby encouraging trained faculty to remain actively involved in the quantum technology ecosystem within Maharashtra.



09 Governance and Monitoring

To ensure effective implementation, coordination across participating institutions, and timely achievement of the program objectives, a multi-tier governance and monitoring framework will be established.

9.1 State Level-Steering Committee

A State-Level Steering Committee chaired by the Additional Chief Secretary, Higher and Technical Education, Government of Maharashtra, will provide strategic oversight for the implementation of the programme. The committee will include the Secretary, Department of Information Technology; Director, Directorate of Technical Education (DTE); representatives from I-Hub QTF at IISER Pune and participating institutions; and domain experts where required.

The committee will provide strategic direction to the program, review overall progress and outcomes, ensure alignment with state priorities in quantum technologies, and support linkages with research institutions and industry.

The Steering Committee will undertake quarterly reviews to assess overall program progress and provide strategic guidance and recommendations for improvement.

9.2 Program Review Committee

A program of such magnitude will require a central monitoring and review process to ensure rapid progress.

It is proposed to set up a Review Committee consisting of Quantum Technology course coordinators from IISER Pune, along with the course coordinators of the four participating institutes. This committee will act as the central body overseeing the progress and effectiveness of the program.

In addition to monitoring program implementation, the committee will also serve a technical advisory role, providing guidance on curriculum development, research priorities, laboratory infrastructure, and emerging developments in quantum technologies.

The committee will review the effectiveness of the courses, assess career opportunities for students, and evaluate the progress of research programs in quantum technologies. Based on these reviews, the committee will also recommend best practices emerging from the experience of the Maharashtra quantum ecosystem for strengthening the program.

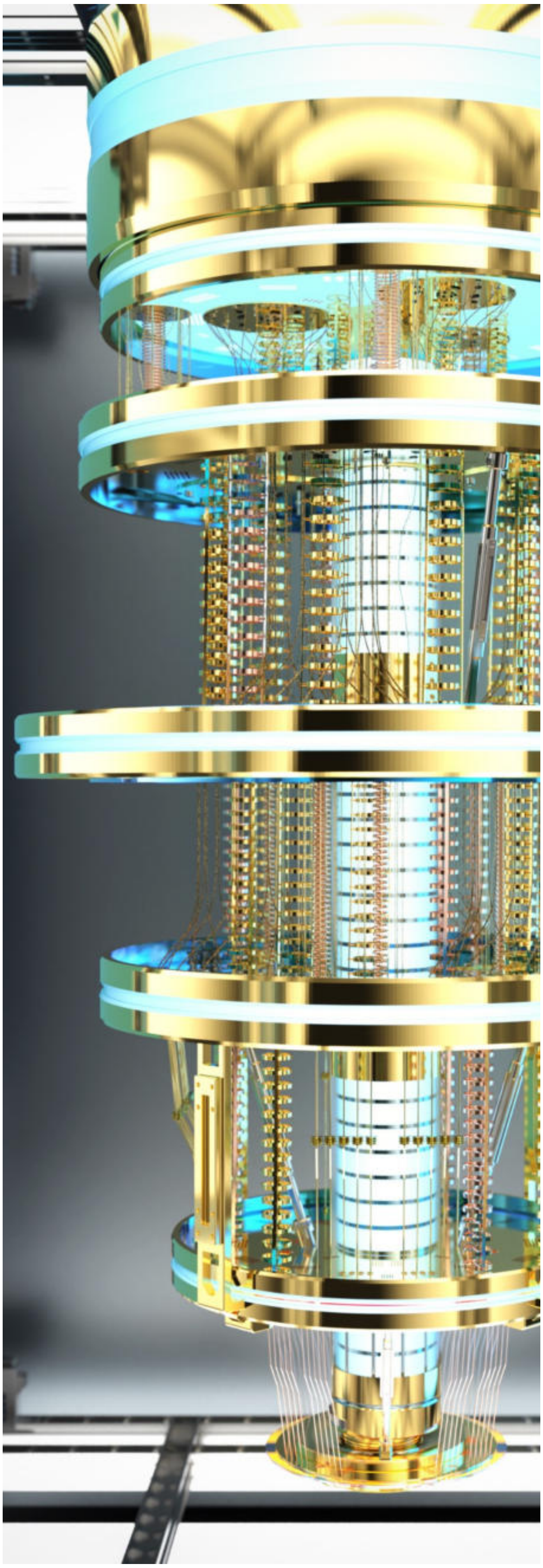
The Review Committee will undertake bi-monthly to assess program progress and provide recommendations for improvement.

9.3 Institutional Level-Implementation Monitoring

At the institutional level, the participating institutes will oversee the day-to-day implementation of the program through the respective Quantum Technology course coordinators.

The institutional teams will monitor the delivery of courses, track student enrolment and participation, and oversee the progress of research activities undertaken under the program.

Review meetings will be conducted twice a month at the institutional level to track progress against the defined activities and deliverables, identify implementation challenges, and ensure timely reporting to the Program Review Committee.



9.4 Evaluation Mechanism

The program will be evaluated based on progress against the defined objectives, deliverables, and phased targets.

Key indicators will include number of faculty trained, rollout of quantum technology courses, student enrolment and completion, establishment and utilization of quantum teaching laboratories, and progress in research activities and collaborations.

The Program Review Committee will assess these indicators during the review process to ensure timely achievement of program outcomes.

9.5 Reporting Mechanism

Each participating institute will submit periodic progress reports through the designated course coordinators to the Program Review Committee.

These reports will capture progress on faculty training, course implementation, student enrolment and completion, research activities, and utilization of infrastructure established under the program. The reports will serve as the primary input for monitoring program implementation and tracking progress against the defined objectives.

Where required, the Program Review Committee may also undertake on-site review visits to participating institutes to assess infrastructure readiness, course delivery, and overall implementation progress.

10 Appendix

10.1 Appendix I: Structure of Train-the-Trainer Faculty Training Program

The Train-the-Trainer program will be conducted in a **hybrid format,** combining **online lectures** with **residential laboratory sessions.** The training modules are designed to provide faculty with both theoretical understanding and hands-on experience in quantum technologies.

The structure of the training program is outlined below:

1. **Total Teaching Hours per Course**
   Each course will consist of **40 hours of instruction,** combining lectures, discussions, and practical sessions.

2. **Number of Courses**
   The Train-the-Trainer program will include **10 courses** covering core areas of quantum technologies.

3. **Quantum Laboratory Training**
   Faculty participants will undergo **10 laboratory sessions of 3 hours each,** conducted in pairs at the **MS Quantum Technologies Laboratory at I-Hub QTF, IISER Pune,** providing hands-on experience with quantum experiments.

4. **Hands-on Sessions on Quantum Algorithms**
   Participants will undertake **weekly supervised sessions** focused on quantum algorithms and programming, with continuous access to **quantum simulation platforms.**

5. **Lecture Sessions**
   The program will include **one-hour lecture sessions across multiple subjects,** covering foundational and advanced topics in quantum technologies. **Online sessions delivered by academic experts and industry practitioners** will complement residential modules and will include **periodic quizzes and assessment**s to evaluate participant progress.

6. **Teaching Experience and Academic Engagement**
   Faculty members from **DBATU, VJTI, COEP, and VNIT** will deliver **two lectures each** to students enrolled in the **MS Quantum Technologies program at IISER Pune,** providing practical exposure to teaching quantum technology courses.

7. **Residential training modules** will be organised during academic breaks, including **short orientation sessions during winter vacations** and **extended training sessions during summer vacations.**

8. During the summer training period, participants will undergo **specialised instruction across key quantum technology domains,** combining theoretical learning with laboratory exposure.

9. Wherever feasible, **online and offline lectures will be recorded** to create a repository of training material for future reference.

Proposed Faculty Training Course Syllabus

The first core module will be completed in the initial three months to build a strong foundation, followed by a second core module over the next three months for advanced topics. Any two electives, aligned with AICTE, will be completed in one month, with selections finalized in the first month to enable preparation and alignment with participant interests.

Module Type	Course Title	Time period
Core Module	Principles of quantum mechanics	3 Months (Hybride)
	Classical and Quantum Information Theory	
	Programming for Quantum Technologies	
	Quantum Technologies lab 1	
Core Module	Introduction to Quantum Sensing	3 Months (Hybride)
	Introduction to Quantum Materials	
	Introduction to Quantum Computation	
	Introduction to Quantum Communication	
	Quantum Technologies lab 2	
Elective (Any Two)	Optimization Problems (Specialisation Elective)	1 Month (Online)
	Classical and Quantum-assisted machine learning	
	Advanced Quantum Algorithms	
	Post Quantum Cryptography	
	Optical Communication	

10.2 Appendix II: Detailed expenditure in each of the Institutes.

A Detailed break-up of costs for I-Hub QTF

ITEM	Expenditure in Cr. Rupees			
	2026-2027	2027-2028	Total	CAPEX/ OPEX
Training :Hosting Faculty at IISER, Consumables to Quantum Lab, Honorarium for Tutors and Teaching Assistants	0.6	0.45	1.05	OPEX
Capacity Building : Honorarium to Instructors; Travel and boarding costs for experts at IISER / other locations, cost for creating online training materials and recording video, Service charges for LMS platform	0.65	0.5	1.15	OPEX
Equipment : Quantum communication teaching tools 1. Biphoton source (Rs. 21 Lakhs from QTESS) 2. BB-92 protocol (Rs. 14 Lakhs from QTESS) 3. HTS based SQUID (Rs. 15 Lakhs)	0.5	-	0.5	CAPEX
Computing / Simulation Resources : Access to Quantum Computer / Quantum Simulator, Create sandbox environment for Quantum in collaboration with NVIDIA/QpiAI/IBM/Yotta, Creating teaching materials.	2.8	3	5.8	OPEX
Incremental operating cost for I-Hub QTF (Overheads as per norms)	0.53	0.47	1	OPEX
Total (A)	5.08	4.42	9.5	-

B Detailed break-up of costs for COEP Technological University, Pune.

Sr. No.	Particular	Activity	FY 2026-27	FY 2026-27
1	Development of Quantum Laboratory Infrastructure (Non-Recurring)	Purchase of Kits and Simulators	0.55 Cr	--
		Workstation: 20 Nos.	0.25 Cr	--
		• HPC Cluster (Small) : 1 Head Node + 4, Compute Nodes (128 Cores total, 512 GB RAM) • GPUs for Hybrid Use: 4-8 NVIDIA A100 or similar for tensor workloads • Storage + Networking : 20 TB NAS, high-speed switch • Access to Real Quantum Hardware: IBM Q, IonQ, or AWS Braket credits • Licenses/Cloud Credits: AWS/GCP/Azure research credits • Cloud Quantum Access: IBM Q, AWS Braket, Xanadu • A few freely available access	--	1.25 Cr
2	Training (Recurring)	FDP/ Symposium/ Summer-Winter Schools/ Conference	0.10 Cr (2 -FDP)	0.20 Cr (2-FDP and 1-Conference)
3	Subscription (Recurring)	IBM Quantum Cloud Platform	0.10 Cr	--
		Online Courses Workshops, Udemy/ Coursera/ QuTech subscriptions	--	0.05 Cr
		Total	1.0 Cr	1.5 Cr

Overall Expenditure Summary

Financial Year	Non-Recurring INR in Crores	Recurring INR in Crores	Total
2026-27	0.80	0.20	1.00
2027-28	1.25	0.25	1.50
Total	2.05	0.45	2.5

C Detailed break-up of costs for Dr Babasaheb Ambedkar Technological University, Lonere.

Financial Year	Activity	Item Description	Manufacturer / Supplier	Quantity	Unit Cost in INR in Crores
2026-27	Quantum Tech Lab (Non-Recurring/CapEx)	Quantum Optics Educational Kits	Thorlabs	1	0.43
		Quantum Eraser Demonstration Kit Metric	Thorlabs	1	0.03
		Quantum Cryptography Analogy Demonstration Kit	Thorlabs	1	0.04
	Recurring	FDP/Workshop	For Affiliated colleges	2	0.10
	Recurring	Cloud Subscriptions	IBM Quantum Experience and D-Wave Quantum platform	2	0.07
Sub-total (A)					0.67
2027-28	Quantum Tech Lab (Non-Recurring/CapEx)	Time-Multiplexed Coherent Ising Machine	Quanfluence	1	0.25
	Workstation for students and HPC-Quantum Hybrid Computing Facility (Non-Recurring/CapEx)	High-end GPU servers (A100/H100 class or equivalent)	NVIDIA	3	1.15
		High-speed networking (InfiniBand / 100GbE)	NVIDIA	1	0.10
		NVIDIA CUDA-Q / cuQuantum enablement & support	NVIDIA	1	0.05
	Recurring	FDP/Workshop	For Affiliated colleges	3	0.20
2027-28		Cloud Subscriptions	IBM Quantum Experience and D-Wave Quantum platform	2	0.08
Sub-Total (B)					1.83
Total (A + B)					2.5

D Detailed break-up of costs for Veermata Jijabai Technological Institute, Matunga

Item Description	Manufacturer / Supplier	Quantity	Unit Cost in INR in Lakhs
Part- I Equipment for Photonic-based Quantum Computing Lab Type of Expenditure: CapEX (INR 1.50 Cr)			
Quantum Optics Educational Kits	Thorlabs	1	0.43
Quantum Eraser Demonstration Kit Metric	Thorlabs	1	0.03
Quantum Cryptography Analogy Demonstration Kit	Thorlabs	1	0.04
High-end GPU servers (A100/H100 class or equivalent)	NVIDIA	2	0.80
CPU compute nodes (multi-core, high RAM)	NVIDIA	2	0.20
High-speed NVMe storage (≥100 TB usable)	NVIDIA	1	0.15
High-speed networking (InfiniBand / 100GbE)	NVIDIA	1	0.10
Subtotal (A)			1.75
Part-II Quantum Computing Research Support, Capacity Building, Student Activity and Outreach Type of Expenditure: CapEX (INR 0.25 Cr)			
Cloud quantum credits (IBM / IonQ / Quantinuum)	NVIDIA		0.05
NVIDIA CUDA-Q / cuQuantum enablement & support, System software, orchestration, schedulers, backups	NVIDIA	1	0.05

Item Description	Manufacturer / Supplier	Quantity	Unit Cost in INR in Lakhs
Training & faculty enablement workshops, conference participation, internships, invited expert talks, Quantum Hackathons, research support, etc	NVIDIA	1	0.15
Subtotal (B)			0.25
Part-III Trapped-Ion Quantum Hardware Teaching Lab Type of Expenditure: CapEX (INR 0.50 Cr)			
Linear Paul trap (macroscopic, teaching grade)	-	1	0.05
UHV chamber with optical access	-	1	0.10
Vacuum pumps (turbo + dry + ion/NEXTORR)	-	1	0.10
RF drive, amplifiers, resonator	-	1	0.05
Optics, AOMs, mounts, fibers	-	1	0.07
EMCCD / single-photon detection system	-	1	0.08
Timing, AWG, FPGA-based control	-	1	0.05
Subtotal (C)	-		0.50
Total of Part-I, II and III (A + B + C)	-		2.50

E Detailed break-up of costs for Visvesvaraya National Institute of Technology Nagpur

Financial Year	Activity	Item Description	Manufacturer / Supplier	Quantity	Unit Cost in INR in Lakhs
2026-27	Quantum Tech Lab (Non-Recurring/CapEx)	Quantum Optics Educational Kits	Thorlabs	1	0.43
		Quantum Eraser Demonstration Kit Metric	Thorlabs	1	0.03
	Workstation for students and HPC-Quantum Hybrid Computing Facility (Non-Recurring/CapEx)	High-end GPU servers (A100/H100 class or equivalent)	NVIDIA	3	1.15
		High-speed networking (InfiniBand / 100GbE)	NVIDIA	1	0.10
		NVIDIA CUDA-Q / cuQuantum enablement & support	NVIDIA	1	0.05
	Recurring	FDP/Workshop	For Affiliated colleges	6	0.30
	Recurring	Cloud Subscriptions	IBM Quantum Experience and D-Wave Quantum platform	2	0.7
Sub-Total (A)					2.13

Financial Year	Activity	Item Description	Manufacturer / Supplier	Quantity	Unit Cost (INR Lakhs)
2027–28	Quantum Tech Lab (Non-Recurring / CapEx)	Time-Multiplexed Coherent Ising Machine	Quanfluence	1	0.25
	Quantum Tech Lab (Non-Recurring / CapEx)	Quantum Cryptography Analogy Demonstration Kit	Thorlabs	1	0.04
	Recurring	FDP / Workshop	For Affiliated Colleges	10	0.50
	Recurring	Cloud Subscriptions	IBM Quantum Experience and D-Wave Quantum Platform	2	0.08
Sub-Total (B)					0.87
Total (A + B)					3.0

10.3 Annexure III: Indicative Curriculum Structure

10.3.1 B. Tech. Minor in Quantum Technology - Course Curriculum Aligned with AICTE's Minor Program in Quantum Technology

Course Category	Course Code	Course Name	Weekly Hours		Examination Scheme			Credit
			L	P	CA	MSE	ESE	
Course offered during Odd Semester								
AICTE	Minor-QT-C01	Foundations of Quantum Computing	3	-	20	20	60	3
AICTE	Minor-QT-C02	Foundations of Quantum Technologies	3	-	20	20	60	3
AICTE	Minor-QT-C03	Basic Laboratory Course for Quantum Technologies	2	2	60	20	20	3
Total (Odd)			8	2	100	60	140	9
Course offered during Even Semester								
AICTE	Minor-QT-C04	Survey of Quantum Technologies and Applications	3	-	20	20	60	3
AICTE	Minor-QT-E05	Elective-I: A. Quantum Computing B. Quantum Communication C. Quantum Sensing D. Quantum Materials	2	2	20	20	60	3
University	Minor-QT-E06	Elective-II: A. Quantum AI B. Quantum Computing for the Pharma Industry C. Quantum Annealing and Optimisation Algorithms D. Project	2	2	20	20	60	3
Total (Even)			7	4	60	60	180	9
Total (Odd + Even)			17	6	160	120	320	18

Students in the Second, Third, and Final year of B.Tech (any disciplines) and B.Pharm can opt for this minor program.

10.3.2 Indicative Courses Syllabus (B. Tech. Minor)

10.3.2.1 Minor-QT-C01 - Foundations of Quantum Computing

1 Qubits vs Classical Bits

- Spin-half systems and photon polarizations
- Trapped atoms and ions
- Artificial atoms using circuits
- Semiconducting quantum dots
- Single and two-qubit gates
- Solovay–Kitaev Theorem

2 Quantum Correlations

- Entanglement
- Bell's Theorems

3 Classical Computation Review

- Turing machines
- Computational complexity: P, NP, PSPACE

4 Reversible Computation

5 Quantum Logic Gates and Circuits

- Universal quantum gates
- Circuit model of computation

6 Quantum Algorithms

- Deutsch Algorithm
- Deutsch–Jozsa Algorithm
- Bernstein–Vazirani Algorithm
- Simon's Algorithm

7 Database Search

- Grover's Algorithm

8 Quantum Fourier Transform & Applications

- Quantum Fourier Transform (QFT)
- Shor's Algorithm (Prime Factorization)

Quantum Complexity Classes

- Q, EQP, BQP, BPP, QMA

9 Additional Topics in Quantum Algorithms

- Variational Quantum Eigensolver (VQE)
- Harrow–Hassidim–Lloyd (HHL) Algorithm
- Quantum Approximate Optimization Algorithm (QAOA)

10 Quantum Error Correction

- Fault tolerance
- Simple error-correcting codes

11 Current Landscape of Quantum Computing

- NISQ-era processors
- Quantum advantage claims
- Future roadmap

12 Course Outcomes

Students completing this course will be able to:

1. Review the basic postulates of quantum mechanics
2. Understand qubits and their physical realizations
3. Work with density operators and time evolution of mixed states
4. Apply principles of quantum gates and circuits
5. Analyze and understand key quantum algorithms
6. Understand fundamentals of quantum error correction

Course References

1. Manenti, R., & Motta, M. (2023). Quantum Information Science. Oxford University Press.
2. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information (10th Anniversary Edition). Cambridge University Press.
3. Pathak, A. (2015). Elements of Quantum Computation and Quantum Communication. CRC Press.
4. Gaitan, F. (2008). Quantum Error Correction and Fault Tolerant Computing. CRC Press.
5. McMahon, D. (2008). Quantum Computing Explained. Wiley.
6. Wong, H. Y. (2022). Introduction to Quantum Computing: From a Layperson to a Programmer in 30 Steps. Springer Nature.

10.3.2.2 Minor-QT-C02 - Foundations of Quantum Technologies

This course is meant for laying down the central theoretical aspects of quantum mechanics in a rigorous manner where students learn the techniques and develop a good intuition for quantum physics.

Course Content and syllabus:

1 Quantum Mechanics (16 - 18 lectures):

Brief overview of classical physics (This segment is meant for the student to understand what a Hamiltonian is, which will feature later in quantum mechanics)

- Hamiltonian function and Hamilton's equations
- Phase-space description of a system
- Connection and Equivalence with Newton's laws for simple systems – free particle, particle moving in a conservative potential, examples of Harmonic oscillator, hydrogen atom

Historical evolution of quantum mechanics

- Planck's quantum hypothesis
- Photo electric effect
- Atomic spectra
- Bohr's quantisation principle
- De Broglie's Wave particle duality

Postulates of Quantum Mechanics

- State vectors and Hilbert Space
- Dirac Bra-Ket notation
- Measurables and Hermitian Operators
- Unitary Transformations
- Schrodinger Equation and Time evolution of quantum states
- Measurement Postulate
- Schrodinger, Heisenberg and Interaction pictures
- Eigen values, Expectation values and Matrix elements
- Heisenberg's Uncertainty principle

Density operator formalism of quantum mechanics – pure and mixed states

- Superposition and Entanglement in quantum mechanics
- No cloning theorem
- Applications of postulates –Particle in a box, Hydrogen atom,
- Harmonic Oscillator
- Number states, ladder operators and Coherent states of a harmonic oscillator
- Spin and Angular momentum – spin half particles
- Rabi problem of a spin-half particle in a rotating magnetic field Minor Degree for UG Degree course in Quantum Technologies 10
- Bosons and Fermions

2 Statistical Physics (8-10 lectures)

- Quick review of first and second laws of thermodynamics
- Thermal Equilibrium and Gibbs principle
- Applying Gibbs principle to Classical and Quantum harmonic oscillators
- Bosons and Fermions and Quantum statistics – Fermi-Dirac and Bose- Einstein distributions

3 Information Science (3-4 lectures)

- Digital communication and information
- Quantifying information in terms of Shannon entropy
- Basic ideas of quantum information
- Decoherence and noise
- Introductory ideas of Kraus operators

4 Brief overview of Computational Complexity (5-6 lectures)

- Qualitative ideas of a Turing machine
- Types of Turing machines
- Time and Space complexity – P vs NP, PSPACE
- Quantum complexity classes – Q, EQP, BQP, BPP, QMA
- Post Quantum Cryptography (PQC)

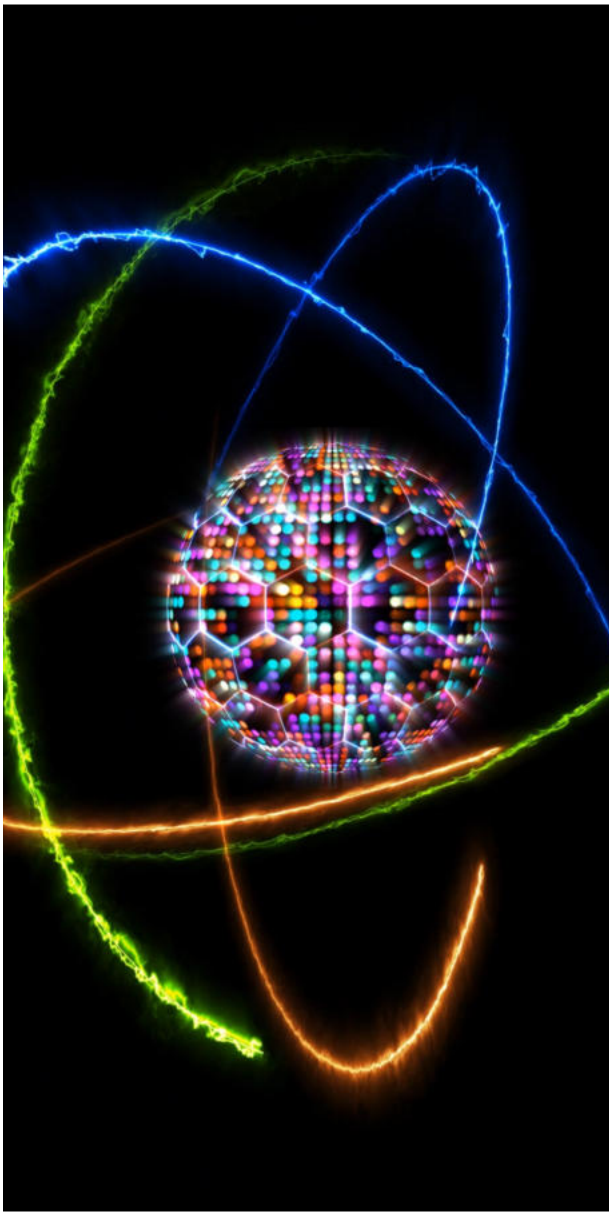
Course Outcomes

Students of this course learn

1. The most relevant mathematical techniques
2. Basic postulates of quantum mechanics and applications
3. Basics of Statistical Physics
4. Basics of Information Science
5. Basics of computational complexity

Course References

1. Introduction to Quantum Mechanics, Griffiths D. J., 3rd Edition, Cambridge University Press (2024)
2. Introduction to Electrodynamics, Griffiths D. J., 4th edition, Cambridge University Press (2020)
3. Principles of Quantum Mechanics, Shankar, R., 2nd edition, Springer (2014)
4. Quantum Information Science – Manenti R., Motta M., 1st Edition, Oxford University Press (2023)
5. Quantum computation and quantum information – Nielsen M. A., and Chuang I. L., 10th
6. Anniversary edition, Cambridge University Press (2010)
7. A Pathak, Elements of Quantum Computation and Quantum Communication, Boca Raton, CRC Press (2015)
8. Information Theory, Robert B. Ash, Dover Publications (2003)
9. Introduction to the Theory of Computation, Michael Sipser, 3rd edition, Cengage India Pvt. Ltd. (2014)
10. Statistical Mechanics, Pathria R. K., Paul D. Beale, 4th edition, Academic Press, (2021)



10.3.2.3 Minor-QT-C03 - Basic Laboratory Course for Quantum Technologies

Course Content and syllabus:

1 Optics

- Interferometry: Wavelength and intensity measurements
- Diffraction: Single slit and grating
- Microscopy: Magnification and aberrations
- Polarization optics: PBS, HWP, QWP

2 RLC Circuits

- Series and parallel RLC circuits
- Verification of quality factor formulae
- Extraction of intrinsic losses

3 Digital Circuits

- Adder and multiplier
- Encoder and decoder
- D flip-flop and shift registers
- Use of common integrated circuit (IC) chips

4 Radio Frequency (RF) Technology

Using oscilloscope

- Ring-up and ring-down time measurements of RLC circuits
- Measurement of pulse shapes using a function generator
- Using vector network analyser (VNA)
- Transmission and reflection measurements (open, short, matched termination)
- Voltage standing wave ratio (VSWR) measurement
- Amplitude and phase quadrature (in-phase and out-of-phase)
- Quality factor measurement of RLC circuits
- Characterization of S-parameters, ABCD and Z matrices of 2-port networks
- Characterization of 3-port networks (directional couplers, circulators, isolators) Using spectrum analyser
- Noise measurement from a resistor at different temperatures

5 Instrumentation and Data Acquisition

- Interfacing instruments with a computer
- Signal demodulation: heterodyne vs homodyne, signal mixing

Sampling and digitisation using ADCs

- Undersampling and aliasing
- Oversampling and noise

- Averaging and interpolation techniques

6 Quantum Simulators and Processors

- Running quantum protocols in a simulator
- Implementing simple quantum algorithms on cloud-based quantum computers
- Running simple algorithms on cloud-based quantum processors (optional)

Course Outcomes

1. Apply basic experimental techniques in optics
2. Characterize resonators and RLC circuits
3. Understand and implement basic digital circuits
4. Apply fundamental RF engineering techniques
5. Interface instruments with computers and perform data acquisition

Course References

1. Hecht, E., & Ganesan, A. R. (2019). Optics (5th ed.). Pearson
2. Horowitz, P., & Hill, W. (2015). The Art of Electronics (3rd ed.). Cambridge University Press
3. Mano, M. M., & Ciletti, M. D. (2018). Digital Design (6th ed.). Pearson
4. Pozar, D. M. (2013). Microwave Engineering (4th ed.). Wiley
5. Oppenheim, A. V., & Schafer, R. W. (2009). Discrete-Time Signal Processing (4th ed.). Pearson
6. Pathak, A., & Banerjee, A. (2016). Optical Quantum Information and Quantum Communication. SPIE Press

10.3.2.4 Minor-QT-C04 - Survey of Quantum Technologies and Applications

Course Content and syllabus:

1 Quantum Technologies – Four Verticals (1 Lecture)

- Motivation for quantum technologies

2 Overview of Quantum Physics (4–5 Lectures)

- Quantum states, wavefunctions, probabilistic interpretation
- Physical observables, Hermitian operators, expectation values
- Heisenberg uncertainty principle
- Schrödinger equation and time evolution
- Distinction from classical physics Superposition, tunnelling, and entanglement (heuristic understanding)
- No-cloning theorem
- Feynman's idea of quantum simulation and origin of the field

3 Quantum Computation (10–12 Lectures)

- Basics of qubits – what is a qubit?
- Difference from classical bits (review of classical logic gates)
- DiVincenzo criteria for realizing qubits
- Basics of quantum gates and circuits
- Physical implementation of qubits (qualitative overview)
- Solid-state qubits
- Semiconductor qubits (quantum dots, spins)
- Superconducting qubits (charge, flux, phase)
- Topological qubits (concepts and advantages)

Atoms and ions

- Trapped ions
- Rydberg atoms
- Neutral atoms

Photonic qubits

- Linear optical systems
- Integrated photonics

NMR qubits

- Conventional NMR systems
- NV centres

Applications and recent achievements

- oRSA and Shor's algorithm
- oQuantum advantage

Long-term goals and strategies

- Quantum error correction

4 Quantum Sensing (8–10 Lectures)

- Basics of quantum sensing
- Photon generation and detection (single and entangled)
- Gravimetry
- Atomic clocks
- Magnetometry
- State-of-the-art developments

5 Quantum Communications (8–10 Lectures)

- Basics of digital communication
- Shannon entropy and classical information
- Fundamentals of quantum communication, security, and eavesdropping

Overview of quantum communication systems

- Fibre-based (terrestrial)
- Free-space and satellite-based

NOTE: Topics on quantum materials are integrated within relevant sections and not treated separately.

Course Outcomes

1. Understand the physical principles behind qubits for computation
2. Analyze different hardware implementations of qubits
3. Understand the basic concepts of quantum sensing
4. Identify applications of quantum sensing
5. Understand implementations of quantum communication in fibre and free-space systems

Course References

1. Manenti, R., & Motta, M. (2023). Quantum Information Science. Oxford University Press
2. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information. Cambridge University Press
3. Pathak, A. (2015). Elements of Quantum Computation and Quantum Communication. CRC Press
4. Kaye, P., Laflamme, R., & Mosca, M. (2006). An Introduction to Quantum Computing. Oxford University Press
5. McMahon, D. (2008). Quantum Computing Explained. Wiley

10.3.3 AICTE Recommended Model Curriculum for M. Tech (Quantum Technology)

Course Code	Course Type	Title	Contact Hours (L:T:P)	Credits
First Semester				
QTM 01	Core	Mathematical Methods for Quantum Technologies	3:1:0	4
QTM 02	Core	Principles of Quantum Mechanics	3:1:0	4
QTM 03	Core	Overview of Quantum Technologies (Seminar)	1:1:0	2
QTM 04	Core	Classical and Quantum Information Theory	3:1:0	4
QTM 05	Core	Programming for Quantum Technologies	0:0:4	2
QTM 06	Core	Quantum Technologies Lab 1	0:0:4	2
QTM 07	Core	Technical Communication	1:1:0	2
Second Semester				
QTM 08	Core	Introduction to Quantum Sensing	3:1:0	4
QTM 09	Core	Introduction to Quantum Materials	3:1:0	4
QTM 10	Core	Introduction to Quantum Computation	3:1:0	4
QTM 11	Core	Introduction to Quantum Communication	3:1:0	4
QTM 12	Core	Quantum Technologies Lab 2	0:0:4	2
Spec Elec 1	Specialisation Elective	Specialisation Elective	3:1:0	4
Third Semester				
Spec Elec 2	Specialisation Elective	Specialisation Elective	3:1:0	4
Spec Elec 3	Specialisation Elective	Specialisation Elective	3:1:0	4
Open Elective 1	Open Elective	Open Elective	3:0:0	3
Open Elective 2	Open Elective	Open Elective	3:0:0	3
Open Elective 3	Open Elective	Open Elective	3:0:0	3
QTM 13	Core	Industry Seminar Course	1:0:0	1
QTM 14*	Core	Project 1	0:0:10	5
Fourth Semester				
QTM 15*	Core	Project 2	0:0:30	15

10.3.4 Indicative Syllabus for Core Courses (M. Tech -Quantum Technology)

10.3.4.1 QTM 01- Mathematical Methods for Quantum Technologies

This course provides an overview of the mathematical methods used in quantum technologies.

Course Content and syllabus:

1 Complex Algebra (Brief Review)

- Complex numbers: real and imaginary parts, Argand plane
- Polar representation

2 Linear Algebra and Matrix Techniques

- Fundamentals of linear algebra
- Matrix methods
- Applications of linear algebra in quantum mechanics

3 Ordinary Differential Equations (ODEs)

Initial value problems

- Applications:
- Harmonic oscillator
- Driven harmonic oscillator

4 Partial Differential Equations (PDEs)

- Boundary value problems:
- Applications:
    - Wave equation
    - Electromagnetic waves

5 Probability and Statistics

- Random variables
- Probability distributions
- Gaussian random variables
    - Law of Large Numberson
    - Central Limit Theorem

Applications in physics:

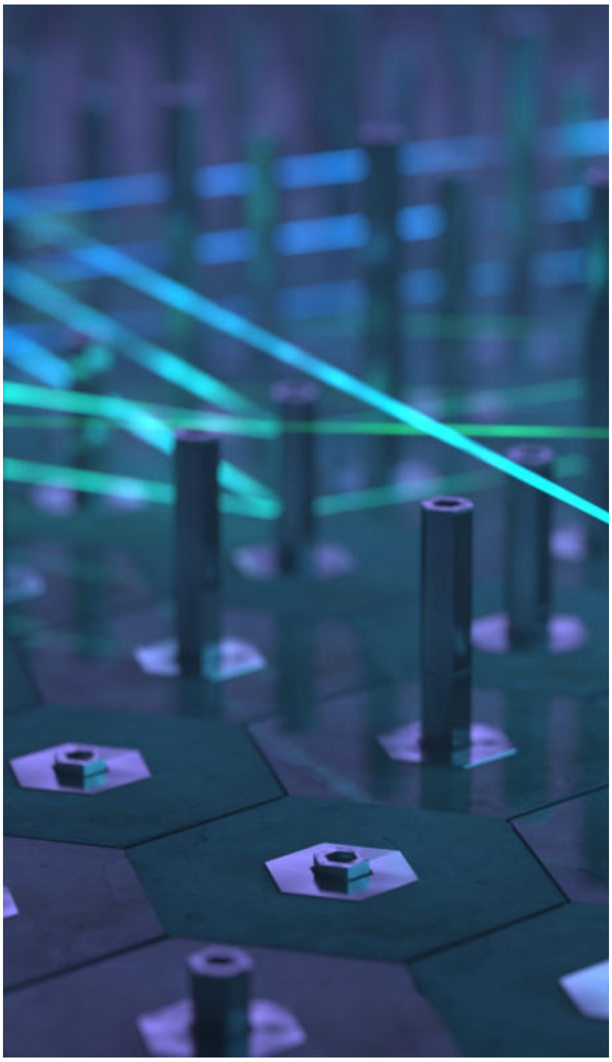
- Gibbs principle
- Average thermal energy and fluctuations
- Noise characterization

Course Outcomes

1. Apply linear algebra and matrix methods to solve problems
2. Solve ordinary and partial differential equations
3. Understand probability and statistical methods
4. Apply mathematical tools in quantum technologies

Course References

1. Kreyszig, E. Engineering Mathematics
2. Garg, R. Engineering Mathematics
3. Arfken, G., & Weber, H. Mathematical Methods for Physicists



10.3.4.2 QTM 02 - Principles of Quantum Mechanics

This course introduces the central theoretical foundations of quantum mechanics in a rigorous manner. It develops mathematical techniques and conceptual understanding required for analysing quantum systems and prepares students for advanced topics in quantum technologies.

1 Postulates of Quantum Mechanics

2 Dirac Bra–Ket Notation

3 One-Dimensional Potential Problems

- Particle in a box
- Potential wells and barriers

4 Approximation Techniques

- Perturbation theory
- Variational techniques

5 Angular Momentum Algebra

- Spin systems
- Identical particles: Bosons and Fermions

6 Density Operator Formalism

- Mixed states
- Limitations of closed quantum systems
- Basic ideas of open quantum systems

7 .Foundational Concepts

- Quantum foundations
- Entanglement and related phenomena

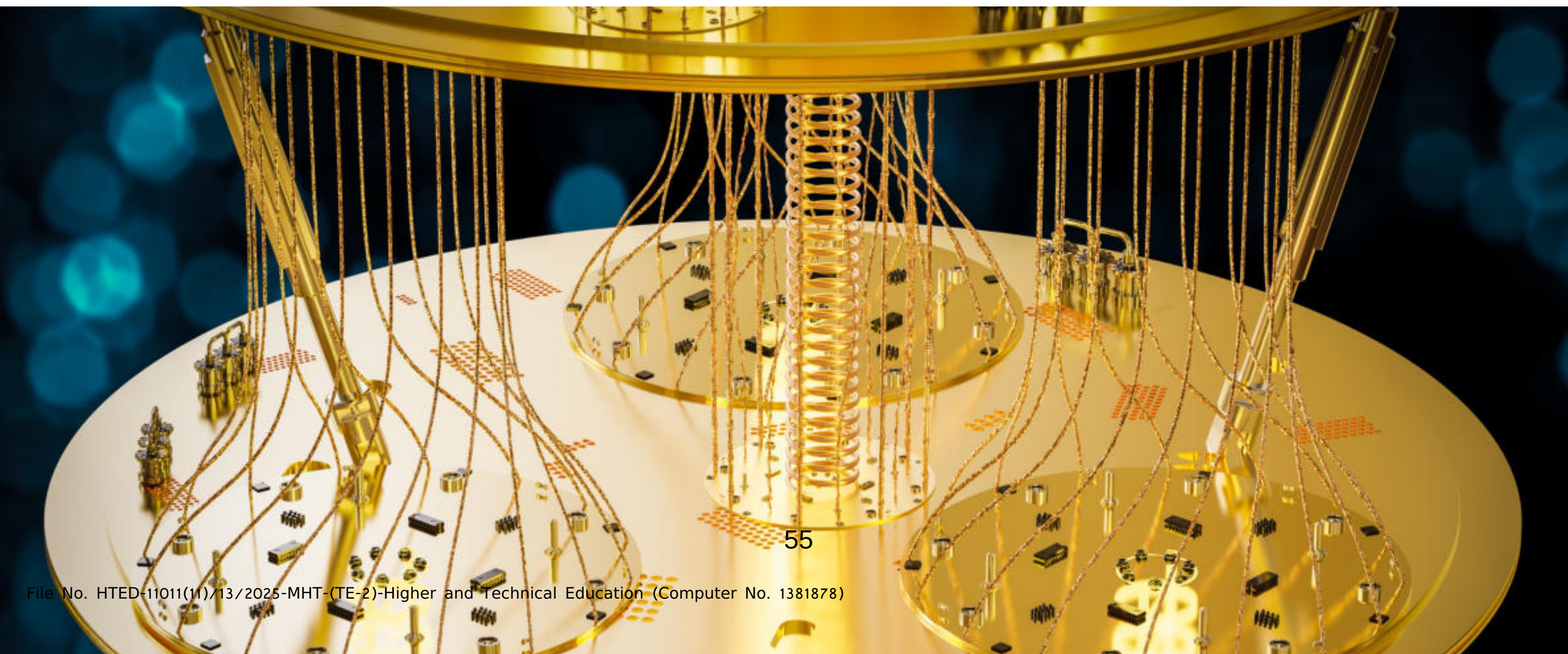
Course Outcomes

Upon completion of the course, students will be able to:

1. Understand the fundamental postulates of quantum mechanics.
2. Solve one-dimensional quantum mechanical potential problems.
3. Apply approximation and variational techniques to quantum systems.
4. Understand the density operator formalism and mixed states.
5. Explain the basic ideas of open quantum systems.
6. Understand foundational concepts such as quantum entanglement.

Course References

1. AICTE Prescribed: Physics (Quantum Mechanics for Engineers), A. Bhattacharya, Khanna Publishing House (2025)
2. Griffiths, D. J., Introduction to Quantum Mechanics, 3rd Edition, Cambridge University Press (2024)
3. Shankar, R., Principles of Quantum Mechanics, 2nd Edition, Springer (2014)
4. Manenti, R., Motta, M., Quantum Information Science, Oxford University Press (2023)
5. Nielsen, M. A., Chuang, I. L., Quantum Computation and Quantum Information, Cambridge University Press (2010)
6. Pathak, A., Elements of Quantum Computation and Quantum Communication, CRC Press (2015)



10.3.4.3 QTM 03- Overview of Quantum Technologies (Seminar)

This course is meant to familiarize students, through weekly seminars, with current developments across all four verticals of quantum technologies. The seminars will also focus on real-life industry use cases to enhance industry readiness.

Course Content and Syllabus

- Weekly seminars by experts from academia and industry
- Student-led seminars on selected topics, encouraging self-study and literature review

Course Outcomes

1. Understand current developments in quantum technologies
2. Develop the ability to conduct self-study and present technical topic.
3. Prepare reports based on seminars attended during the course

Course References

1. Bhattacharya, A. Foundations of Quantum Technologies. Khanna Publishing House

10.3.4.4 QTM 04- Classical and Quantum Information Theory

Course Content and Syllabus

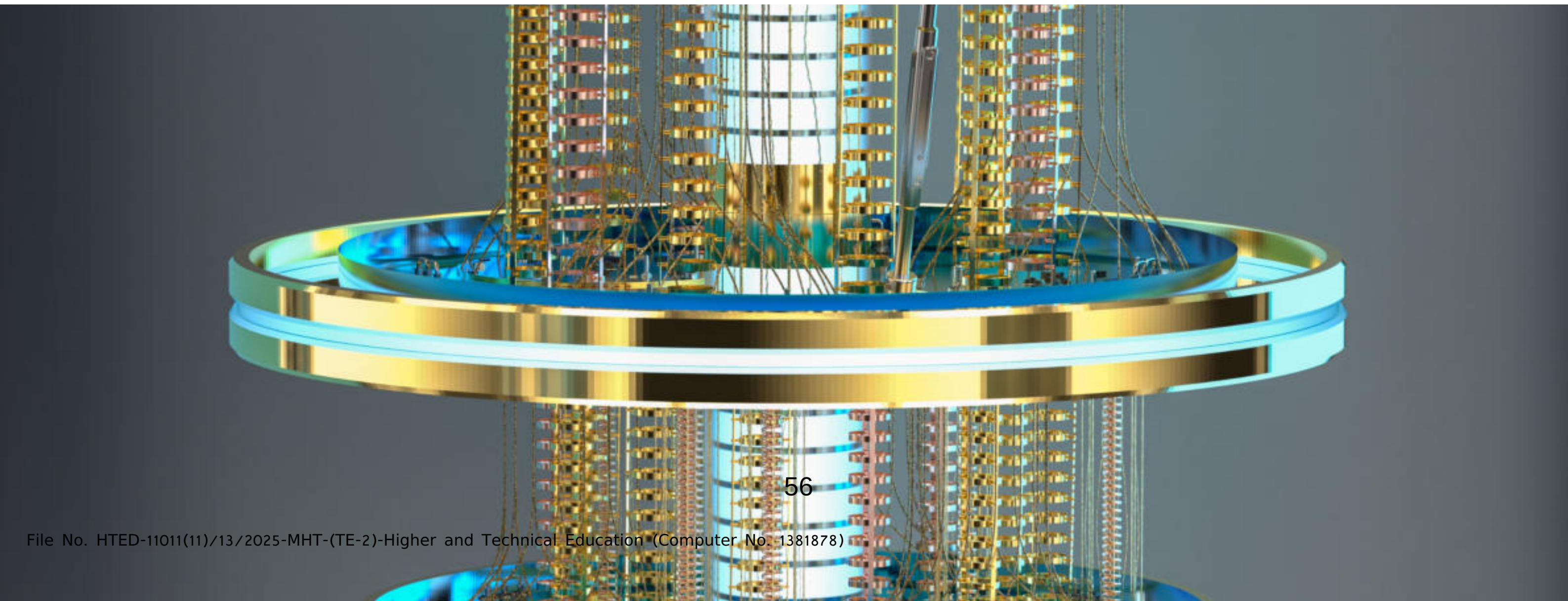
- Basics of classical information theory – Shannon information entropy
- Noiseless channel encoding
- Noisy channel encoding
- von Neumann entropy
- Entanglement and its measures
- Quantum channel capacity
- Heuristic ideas of classical networks
- Quantum networks and quantum repeaters
- Quantum communication protocols

Course Outcomes

1. Understand the basics of classical information theory
2. Understand the fundamentals of quantum information theory
3. Understand key quantum communication protocols

Course References

1. Manenti, R., & Motta, M. (2023). Quantum Information Science. Oxford University Press
2. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information. Cambridge University Press
3. Pathak, A. (2015). Elements of Quantum Computation and Quantum Communication. CRC Press
4. Bhattacharya, A. (2025). Introduction to Quantum Communication. Khanna Publishing House



10.3.4.5 QTM 05- Programming for Quantum Technologies

This course introduces the fundamentals of programming and computational tools used in quantum technologies, along with exposure to key frameworks and simulation platforms.

Course Content and Syllabus

Basics of programming

- Data structures

Basics of algorithms

- Sorting
- Searching

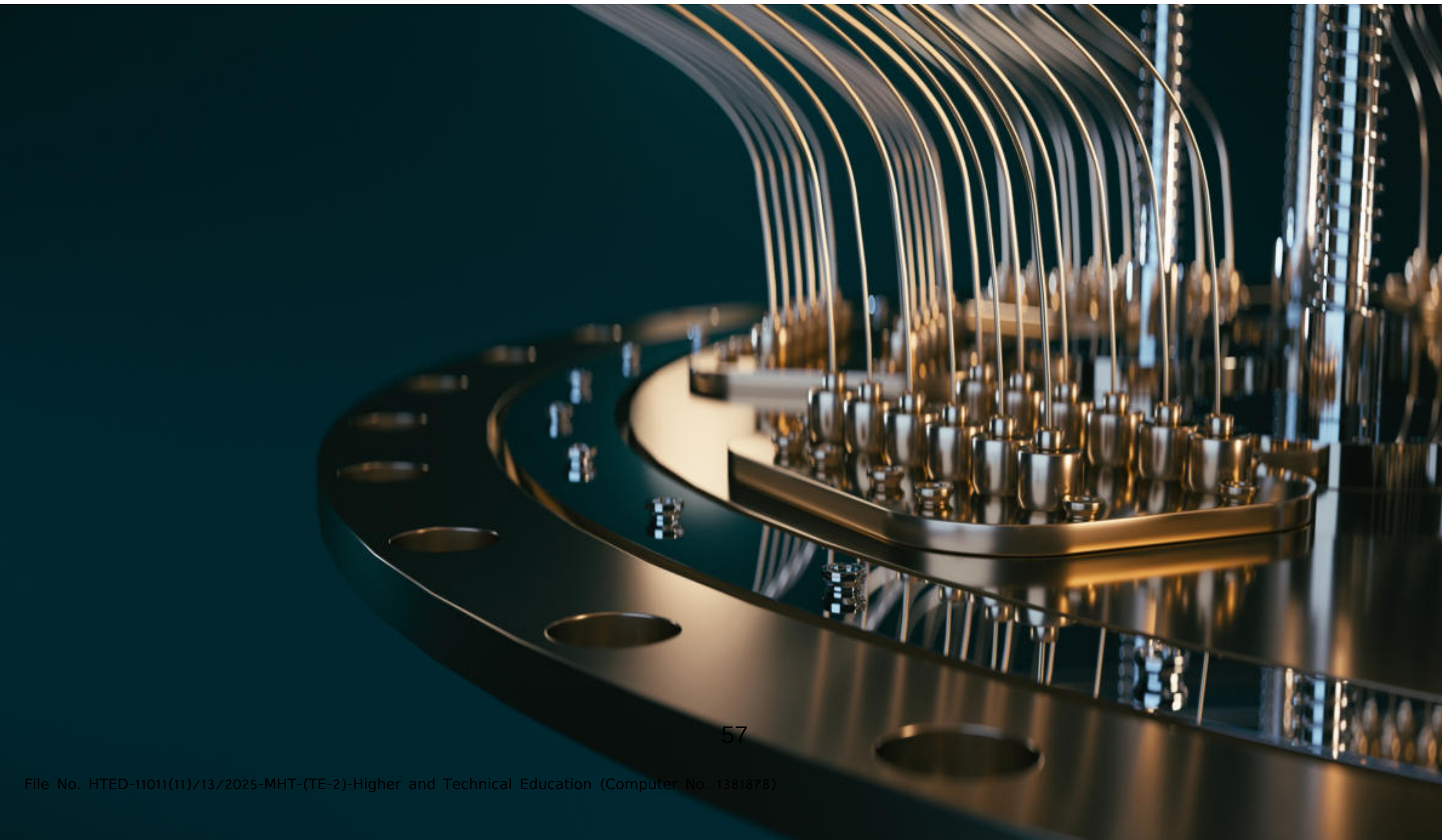
- Basics of Python
- Basics of Julia
- Basics of QASM
- Using toolboxes for quantum technologies in these languages
- Simulation of simple closed and open quantum systems (e.g., QuTiP)
- Use of frameworks such as Cirq, PennyLane, and Qiskit

Course Outcomes

1. Understand the fundamentals of programming
2. Gain working knowledge of Python, Julia, and QASM
3. Use toolboxes for quantum technology applications
4. Apply frameworks such as Cirq, PennyLane, and Qiskit

Course References

1. NVIDIA. CUDA-Q Documentation – https://nvidia.github.io/cuda-quantum/latest/index.html
2. Qiskit Textbook (2023) – https://github.com/Qiskit/textbook
3. Official Python Tutorial – https://docs.python.org/3/tutorial/index.html
4. Downey, A. B. (2015). Think Python: How to Think Like a Computer Scientist (2nd ed.). O'Reilly
5. Jose, J. (2021). Taming Python by Programming. Khanna Publishing House



10.3.4.6 QTM 06 - Quantum Technologies Lab 1

This course introduces the fundamentals of digital and analog electronics, along with basic optical systems and experiments relevant to quantum technologies.

Course Content and Syllabus

1 Digital electronics – logic gates
- Combinational circuits
  - Half and full adder
  - Decoder and encoder
- Sequential circuits
  - Flip-flops and shift registers

2 Analog electronics
- RLC filters
  - Frequency domain modelling of RLC circuitsers
  - Low-pass and high-pass characteristics
  - Quality factor
- Diode circuits
  - Rectification and envelope detection
- Operational amplifier (Op-Amp) circuits
  - Inverting and non-inverting amplifiers
  - Adder circuits

3 Simple experiments demonstrating quantum nature Combinational circuits
- Franck–Hertz experiment
- Photoelectric effect
- Balmer spectral lines
- Compton scattering
- Band gap of semiconductors

4 Basics of optical bench

5 Linear optical elementsFranck–Hertz experiment
- Beam splitters
- Polarizers, half-wave plates, full-wave plates
- Diffraction gratings

6 Michelson interferometer on an optical bench

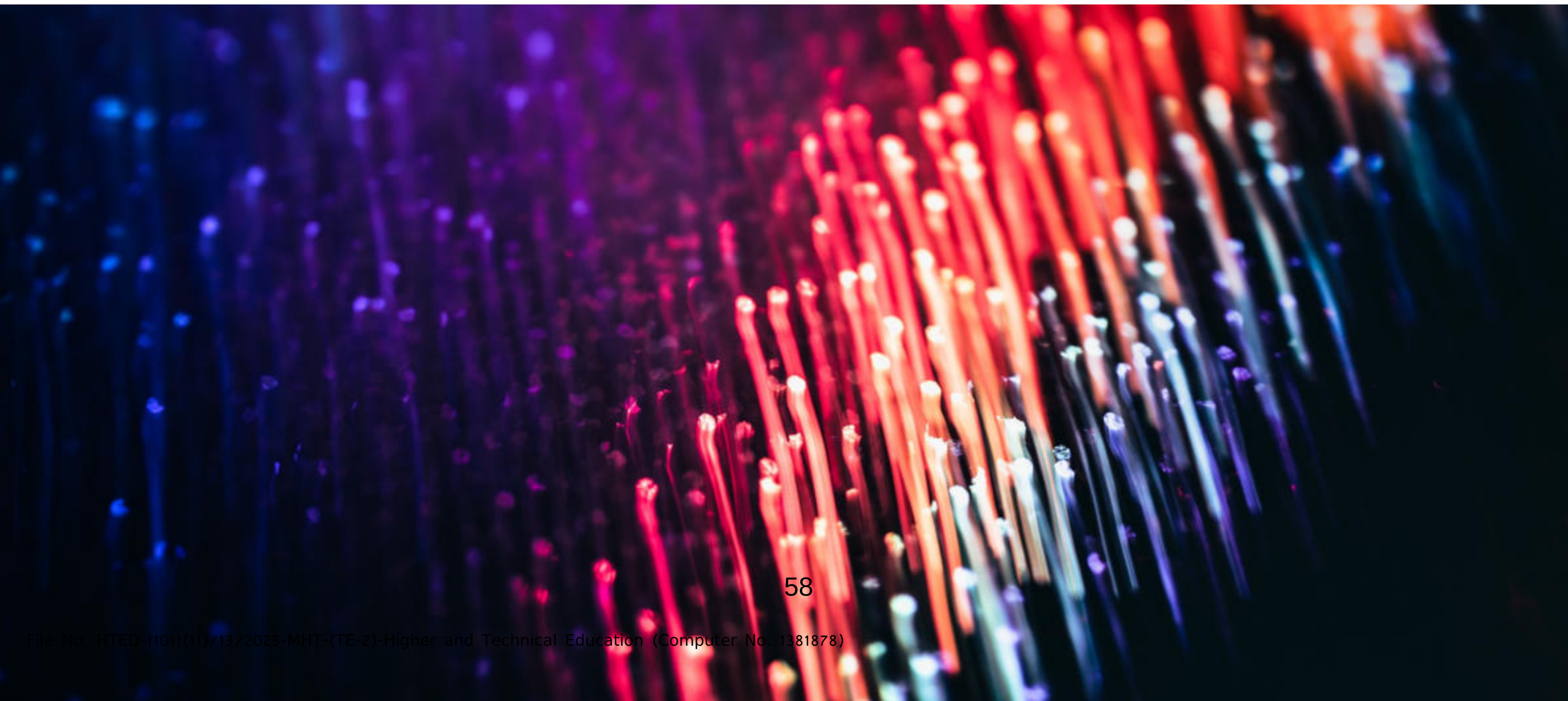
7 Mach–Zehnder interferometer (optional)

Course Outcomes

1. Understand fundamentals of digital electronics and logic gates
2. Understand basic analog circuits and components
3. Understand optical experiments including polarization and interference

Course References

1. Boylestad, R., & Nashelsky, L. Electronic Devices and Circuit Theory. Pearson
2. Lipson, S. G. Optics Experiments and Demonstrations for Student Laboratories. IOP Publishing
3. Maini, A. K. Analog Electronics. Khanna Publishing House
4. Tilak, A. V. N. Design of Analog Circuits. Khanna Publishing House
5. Saleh, B. E. A., & Teich, M. C. Fundamentals of Photonics (3rd ed.)



10.3.4.7 QTM 07 - Technical Communication

This course focuses on developing scientific communication, research analysis, and technical writing skills essential for quantum technologies.

Course Content and Syllabus

- Student seminars on selected scientific topics
- Written term papers on scientific topics
- Literature survey and research paper analysis
- Popular science communication

Course Outcomes

1. Develop basics of technical writing
2. Develop technical oral communication skills
3. Analyze research papers
4. Communicate scientific ideas to broader audiences

Course References

1. Sharma, P. Effective Technical Communication. Khanna Publishing House
2. Kumar, K. Effective Communication Skills. Khanna Publishing House

10.3.4.8 QTM 08 - Introduction to Quantum Sensing

This course introduces the principles of classical and quantum sensing, measurement theory, and advanced sensing applications using quantum systems.

Course Content and Syllabus

1. Classical sensing
   - Photodetection
2. Classical noise
   - Johnson noise
   - Telegraph noise
   - Flicker (1/f) noise
3. Sensitivity of classical measurements
   - Classical Fisher information
   - Cramér–Rao bounds
4. Quantum measurements
   - Projective (orthogonal) measurements
   - Approximate (non-orthogonal) measurements
   - Weak continuous measurements
   - Error–disturbance relations
   - Standard quantum limits
   - Quantum non-demolition measurements
5. States of light
   - Fock states
   - Coherent states
   - Squeezed states
   - Quantum state tomography
   - Wigner quasi-probability distribution
   - P-distribution
   - Husimi Q function
6. Quantum photodetection
   - Square-law detectors, intensity measurements
   - Linear detectors and quadrature measurements
7. Quantum Cramér–Rao bounds
8. Single photon-based sensing applications
9. Entanglement-based sensing applications
10. Atomic and solid-state sensing
    - Atomic state-based sensing
    - Spin-based sensing
    - Applications: gravimetry, magnetometry

Course Outcomes

1. Understand classical sensing and noise
2. Understand principles of quantum measurement
3. Understand fundamentals of quantum sensing
4. Apply quantum Cramér–Rao bounds
5. Analyze single-photon and entanglement-based sensing applications

Course References

1. Wiseman, H., & Milburn, D. (2014). Quantum Measurement and Control. Cambridge University Press
2. Braginsky, V., & Khalili, F. (1995). Quantum Measurement. Cambridge University Press
3. Manenti, R., & Motta, M. (2023). Quantum Information Science. Oxford University Press

10.3.4.9 QTM 09- Introduction to Quantum Materials

This course introduces the fundamental concepts of quantum materials, including electronic structure, magnetism, superconductivity, and emerging material systems relevant to quantum technologies.

Course Content and Syllabus

1. Band theory basicsMetals, semiconductors, and insulators
   - Metals, semiconductors, and insulators
   - Band structure of solids
   - Survey of semiconducting devices for quantum technologies (electronic and quantum optical devices and their principles of operation)

2. Correlated systems

3. Magnetism
   - Paramagnetism and ferromagnetism basics
   - Magnetic measurements, Hall effect, magnetoresistance
   - Faraday and Kerr effects

4. Superconductivity
   - BCS theory
   - Ginzburg–Landau theory
   - Josephson effect (AC and DC)
   - Survey of superconducting devices for quantum technologies

5. Two-dimensional (2D) materials
   - Graphene: properties of single and few layers
   - Transition metal dichalcogenides (TMDCs): electronic and optical properties

6. Topological phases of matter
   - Basics of topology
   - Geometric phases (Berry phase)
   - Aharonov–Bohm effect
   - Topological phases of matter

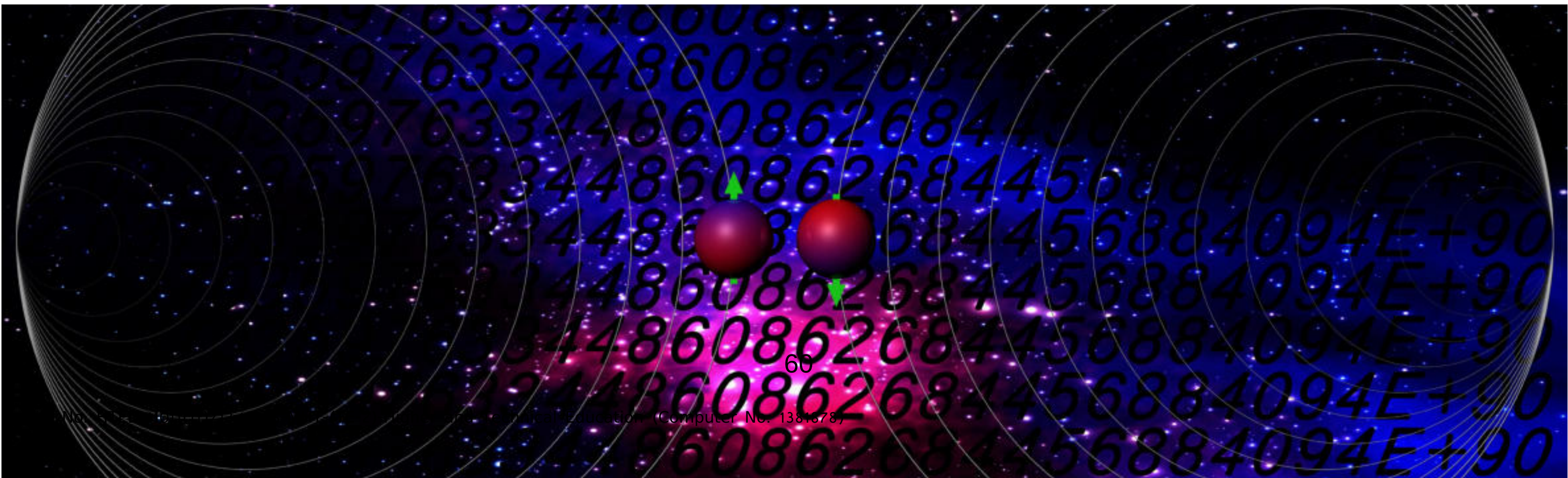
7. Material growth techniques
   - Molecular beam epitaxy (MBE)
   - Chemical vapor deposition (CVD), MOVPE
   - Pulsed laser deposition (PLD)
   - Crystal growth techniques

Course Outcomes

1. Understand the basic concepts of quantum materials
2. Understand band theory of solids
3. Understand fundamentals of magnetism
4. Understand basics of superconductivity
5. Understand emerging 2D materials such as graphene and TMDCs
6. Understand topology and topological phases of matter

Course References

1. Bhattacharya, A. (2025). Physics (Quantum Mechanics for Engineers). Khanna Publishing House
2. Marder, M. P. (2010). Condensed Matter Physics (2nd ed.). Wiley
3. Tinkham, M. (2017). Introduction to Superconductivity. MedTech



10.3.4.10 QTM 10 - Introduction to Quantum Computation

This course introduces the theoretical foundations of quantum computation, including qubits, quantum algorithms, computational complexity, and error correction.

1 Qubits versus classical bits
- Spin-half systems and photon polarizations
- Trapped atoms and ions
- Artificial atoms using circuits
- Semiconducting quantum dots
- Single and two-qubit gates – Solovay–Kitaev theorem

2 Quantum correlations
- Entanglement and Bell's theorems

3 Review of Turing machines and classical computational complexity
- Time and space complexity (P, NP, PSPACE)

4 Reversible computation

5 Universal quantum logic gates and circuits

6 Quantum algorithms
- Deutsch algorithm
- Deutsch–Jozsa algorithm
- Bernstein–Vazirani algorithm
- Simon's algorithm

7 Database search
- Grover's algorithm

8 Quantum Fourier transform and prime factorization
- Shor's algorithm

9 Quantum complexity classes
- Q, EQP, BQP, BPP, QMA

10 Additional topics in quantum algorithms
- Variational Quantum Eigensolver (VQE)
- HHL algorithm
- Quantum Approximate Optimization Algorithm (QAOA)

11 Introduction to error correction
- Fault tolerance
- Simple error-correcting codes

12 Survey of current status
- NISQ-era processors
- Quantum advantage claims
- Future roadmap

Course Outcomes

1. Understand classical sensing and noise
2. Understand principles of quantum measurement
3. Understand fundamentals of quantum sensing
4. Apply quantum Cramér–Rao bounds
5. Analyze single-photon and entanglement-based sensing applications

Course References

1. Manenti, R., & Motta, M. (2023). Quantum Information Science. Oxford University Press
2. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information. Cambridge University Press
3. Pathak, A. (2015). Elements of Quantum Computation and Quantum Communication. CRC Press
4. Gaitan, F. (2008). Quantum Error Correction and Fault Tolerant Computing. CRC Press
5. Chopra, R. (2025). Quantum Computing & Techniques. Khanna Publishing House
6. 6. McMahon, D. (2008). Quantum Computing Explained. Wiley
7. 7. Wong, H. Y. (2022). Introduction to Quantum Computing. Springer

10.3.4.11 QTM 11 - Introduction to Quantum Communication

This course introduces the fundamental concepts of quantum materials, including electronic structure, magnetism, superconductivity, and emerging material systems relevant to quantum technologies.

Course Content and Syllabus

1. Basics of polarization optics
   - Quarter-wave and half-wave plates
   - Polarizing beam splitters
2. Basics of detectors
   - Paramagnetism and ferromagnetism basics
   - Magnetic measurements, Hall effect, magnetoresistance
   - Faraday and Kerr effects
3. Digital communication and information theory (basics)
   - Information entropy
   - Noiseless channel encoding
   - Noisy channel encoding
4. No-cloning theorem
5. Quantum memories
6. Quantum repeaters
7. Entanglement and Bell's theorems
8. Bell measurements and tests
9. Quantum teleportation protocol
10. Quantum dense coding
11. Quantum key distribution (QKD) protocols
    - BB84
    - B92
    - E91
    - COW
    - BBM92
    - DPS
12. Quantum networks and quantum internet
13. Survey of hardware implementations
    - Free-space communication
    - Satellite-based communication
    - Fibre-optic communication

Course Outcomes

1. Understand basics of electromagnetic (EM) theory
2. Understand principles of photodetection
3. Understand fundamentals of information theory
4. Understand core concepts in quantum communication

Course References

1. Nielsen, M. A., & Chuang, I. L. (2010). *Quantum Computation and Quantum Information*. Cambridge University Press
2. Pathak, A. (2015). *Elements of Quantum Computation and Quantum Communication*. CRC Press
3. Bhattacharya, A. (2025). *Introduction to Quantum Communication*. Khanna Publishing House

10.3.4.12 QTM 12 - Quantum Technologies Lab 2

This course focuses on advanced experimental techniques in RF, optics, and quantum systems, along with simulations and implementation of quantum algorithms.

Course Content and Syllabus

1 RF electronics

- IQ modulation and demodulation

2 Noise spectral measurements

3 Correlation and coherence measurements

- FPGA electronics
- Coherent sources
- Thermal noise sources

4 Optics

- Mach–Zehnder interferometer
- Coherence measurements of light sources
- Single-photon detection

5 Quantum experiments (free space)

- Heralded photon and entangled photon generation, measurement, and validation
- Hong–Ou–Mandel (HOM) experiments and quantum state tomography
- Grangier experiment
- Bell test experiments
- Quantum optical gate realization
- Single-photon interferometry (MZI/Sagnac)
- Biphoton experiments
- Applications: quantum random number generator using entangled sources
- BB84 protocol implementation

6 Simulation of open quantum systems

7 Running quantum algorithms

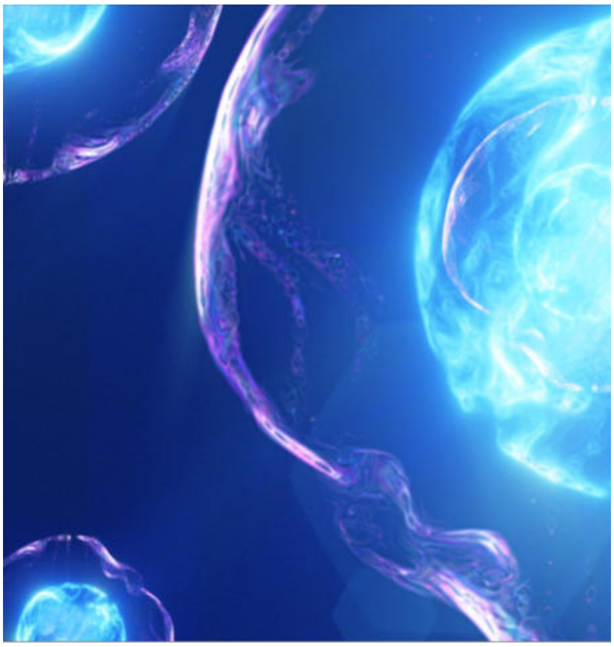
- On classical simulators
- On cloud-based quantum processors (subject to availability)

Course Outcomes

1. Perform advanced RF and microwave experiments
2. Work with FPGA-based electronics
3. Conduct advanced optical experiments
4. Perform experiments with single and entangled photons
5. Simulate open quantum systems
6. Run quantum algorithms on simulators and available quantum processors

Course References

1. Bachor, H.-A., & Ralph, T. C. A Guide to Experiments in Quantum Optics (2nd ed.). Wiley-VCH
2. Bhattacharya, A. Foundations of Quantum Technologies. Khanna Publishing House



10.4 Annexure IV: Bill of Quantities

HARDWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
Quantum Optics Educational Kit	Complete photonic QT lab; single-photon source, entanglement, interference, Bell test	DBATU	Thorlabs	1	43	43	–	43
Quantum Eraser Demonstration Kit	Wave-particle duality demonstrator, coincidence counting	DBATU	Thorlabs	1	3	3	–	3
Quantum Cryptography Analogy Demo Kit	BB84/BB92 protocol hardware analogy using polarised photons	DBATU	Thorlabs	1	4	4	–	4
Time-Multiplexed Coherent Ising Machine	Quantum-inspired optical optimisation system, QUBO-capable	DBATU	Quanfluence	1	25	–	25	25
High-end GPU Servers (A100/H100 class)	3× DGX-class servers; 80 GB HBM per GPU; NVLink interconnect	DBATU	NVIDIA	3	~38	–	115	115
High-speed Networking (InfiniBand/100GbE)	HDR InfiniBand or 100GbE switch for GPU cluster interconnect	DBATU	NVIDIA	1	10	–	10	10
Quantum Optics Educational Kit	Complete photonic QT lab; single-photon source, SPDC, Bell test	VJTI	Thorlabs	1	43	43	–	43

HARDWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
Quantum Eraser Demonstration Kit	Wave-particle duality and measurement back-action demonstrator	VJTI	Thorlabs	1	3	3	–	3
Quantum Cryptography Analogy Demo Kit	BB84/BB92 hardware analogy using polarised photons	VJTI	Thorlabs	1	4	4	–	4
High-end GPU Servers (A100/H100 class)	2× DGX-class servers; 80 GB HBM per GPU; NVLink interconnect	VJTI	NVIDIA	2	40	80	–	80
CPU Compute Nodes (multi-core, high RAM)	2× multi-core nodes; high RAM for classical optimisation loops	VJTI	NVIDIA/ OEM	2	10	20	–	20
High-speed NVMe Storage (≥100 TB usable)	NVMe all-flash array, ≥100 TB usable capacity	VJTI	NVIDIA/ OEM	1	15	15	–	15
High-speed Networking (InfiniBand/ 100GbE)	HDR InfiniBand or 100GbE switch	VJTI	NVIDIA	1	10	10	–	10
Linear Paul Trap (teaching grade)	Macroscopic Paul trap for ion trapping demonstrations	VJTI	Supplier TBD	1	5	5	–	5

HARDWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
UHV Chamber with Optical Access	CF chamber with viewports for optical access	VJTI	Supplier TBD	1	10	10	–	10
Vacuum Pumps (turbo + dry + ion/NEXTORR)	UHV-compatible pump set	VJTI	Supplier TBD	1 set	10	10	–	10
RF Drive, Amplifiers, Resonator	Trap drive and control electronics	VJTI	Supplier TBD	1 set	5	5	–	5
Optics, AOMs, Mounts, Fibers	Beam control and modulation components	VJTI	Supplier TBD	1 set	7	7	–	7
EMCCD / Single-Photon Detection System	Single-ion fluorescence imaging camera	VJTI	Supplier TBD	1	8	8	–	8
Timing, AWG, FPGA-based Control	Pulse sequencer and arbitrary waveform generator	VJTI	Supplier TBD	1 set	5	5	–	5
Quantum Optics Educational Kit	Complete photonic QT lab; single-photon source, entanglement	VNIT	Thorlabs	1	43	43	–	43

HARDWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
Quantum Eraser Demonstration Kit	Wave-particle duality demonstrator	VNIT	Thorlabs	1	3	3	—	3
High-end GPU Servers (A100/H100 class)	3× DGX-class servers; 80 GB HBM per GPU	VNIT	NVIDIA	3	~38	115	—	115
High-speed Networking (InfiniBand/ 100GbE)	HDR InfiniBand or 100GbE switch	VNIT	NVIDIA	1	10	10	—	10
Quantum Cryptography Analogy Demo Kit	BB84/BB92 hardware analogy using polarised photons	VNIT	Thorlabs	1	4	—	4	4
Time-Multiplexed Coherent Ising Machine	Quantum-inspired optical optimisation system	VNIT	Quanfluence	1	25	—	25	25
Purchase of Kits & Simulators	128 cores total; 512 GB RAM; for tensor workloads	COEP	OEM	1	55	—	55	55
Student Workstations	20 workstations for lab access	COEP	Dell/HP	20	~1.25	—	25	25

HARDWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
HPC Cluster (Small) : 1 Head Node + 4, Compute Nodes (128 Cores total, 512 GB RAM) GPUs for Hybrid Use: 4-8 NVIDIA A100 or similar for tensor workloads Storage + Networking : 20 TB NAS, high-speed switch Access to Real Quantum Hardware: IBM Q, IonQ, or AWS Braket credits Licenses/Cloud Credits: AWS/GCP/Azure research credits Cloud Quantum Access: IBM Q, AWS Braket, Xanadu A few freely available access	4–8 GPU cards for hybrid QC workloads	COEP	NVIDIA	4–8	—	—	50	125
Quantum Communication Teaching Tools	Biphoton source (Rs.21L), BB-92 protocol demo (Rs.14L), HTS SQUID (Rs.15L) — via QTESS	IISER	QTESS/ Thorlabs	3 items	—	50	—	50

SOFTWARE								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
NVIDIA CUDA-Q / cuQuantum Enablement & Support	Enterprise simulation framework; multi-GPU quantum circuit simulation	DBATU	NVIDIA	1 licence	5	–	5	5
NVIDIA CUDA-Q / cuQuantum Enablement & Support	Enterprise simulation framework; system software, orchestration, schedulers, backups	VJTI	NVIDIA	1 licence	5	5	–	5
NVIDIA CUDA-Q / cuQuantum Enablement & Support	Enterprise simulation framework; multi-GPU quantum circuit simulation	VNIT	NVIDIA	1 licence	5	5	–	5

CLOUD								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
IBM Quantum Experience + D-Wave Leap	Cloud QPU access; IBM Quantum Premium Plan; D-Wave Leap optimisation platform	DBATU	IBM / D-Wave	2 platforms	–	7	8	15
IBM Quantum / IonQ / Quantinuum Cloud Credits	Hybrid QPU execution credits; NISQ system access	VJTI	IBM/IonQ/ Quantinuum	5 credits	1	5	–	5

CLOUD								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
IBM Quantum Experience + D-Wave Leap	Cloud QPU access; IBM Quantum Premium; D-Wave Leap	VNIT	IBM / D-Wave	2 platforms	—	7	8	15
IBM Quantum Cloud Platform Subscription	IBM Quantum Premium Plan for institutional access	COEP	IBM	1	—	10	0	10
Quantum Simulation & Cloud Access (NVIDIA/QPiAI/ IBM/Yotta)	CUDA-Q sandbox; IBM Quantum System 2 (133 qubits); QPiAI; Yotta HPC	IISER	NVIDIA/ IBM/ QPiAI/ Yotta	Consortium-wide	—	280	300	580

MANPOWER & TRAINING								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
FDPs for Affiliated Colleges	One-week residential FDPs; expert faculty; lab sessions	DBATU	DBATU / I-Hub	2 FY26 / 3 FY27	5	10	20	30
Training, Workshops, Hackathons, Internships	Faculty enablement workshops, conference participation, invited expert talks, hackathons, research support	VJTI	VJTI / External	—	—	15	—	15

MANPOWER & TRAINING								
Item Description	Technical Specification	Institute	Vendor / Supplier	Qty	Unit Cost (Rs.L)	FY 2026-27 (Rs.L)	FY 2027-28 (Rs.L)	Total (Rs.L)
FDPs for Affiliated Colleges	One-week residential FDPs; expert faculty; lab sessions	VNIT	VNIT / I -Hub	6 FY26 / 10 FY27	5	30	50	80
FDP / Symposium / Summer-Winter Schools	FDPs + symposium + conference for faculty and students	COEP	COEP / I-Hub	2 FY26 / 2 FY27	5	10	20	30
Online Course Subscriptions (Udemy/Coursera/QuTech)	Online quantum computing and QT courses for self-paced learning	COEP	Online Platforms	—	—	5	—	5
Training: Hosting Faculty at IISER (consumables, honoraria for TAs)	Residential FDP hosting; lab consumables; teaching assistant honoraria	IISER	I-Hub QTF	2 cohorts/ yr	—	60	45	105
Capacity Building: Expert Honoraria, Travel, LMS, Video Recording	Honoraria for instructors; travel and boarding; online material creation; LMS service charges	IISER	I-Hub QTF	—	—	65	50	115
I-Hub QTF Operating Overheads (DST norms)	Staff, administration, monitoring and reporting	IISER	I-Hub QTF	—	—	53	47	100