课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	IQS5001 量子信息前沿选讲, Frontier Lectures in Quantum Information Science
2.	**课程性质** **Compulsory/Elective**	选修, Elective
3.	**课程学分/学时** **Course Credit/Hours**	3.0/48H
4.	**授课语言** **Teaching Language**	中文, Chinese
5.	**授课教师** **Instructor(s)**	王玉成，贺煜，尉石，陈廷勇、宋学锋等 Wang Yucheng, He Yu, Yu Shi, Chen Tingyong, Song Xuefeng, etc.
6.	**先修要求** **Pre-requisites**	高等量子力学、固体物理、量子计算、量子比特、原子分子物理、电磁学 Advanced Quantum Mechanics、Solid State Physics、Quantum Computation、Quantum Bits、Atomic Physics、 Electromagnetism
7.	**教学目标** **Course Objectives**	

量子信息科学最近发展非常迅速，本课程主要介绍量子信息与计算领域的最新进展，包括拓扑材料、量子计算、精密测量及量子工程应用四个部分。本课程旨在帮助学生了解量子信息科学的国际前沿动态、量子计算的未来趋势、量子科技革命的工程价值和技术挑战，激发学生对量子科技的好奇心与探索热情。

拓扑材料方向主要学习拓扑物态相关的基础物理，包括拓扑能带理论、拓扑绝缘体、拓扑超导体、拓扑半金属及拓扑量子计算等相关物理的概念，图像，模型和相关的材料系统，最后大致介绍本领域的一些最新研究。

量子计算部分将聚焦几个关键的量子计算实验物理体系的最新前沿动态：超导量子计算、自旋磁共振量子计算、离子阱量子计算、硅基量子计算、量子测量控制理论前沿。量子计算相关的基础课程请参考物理系、及量子院的其他课程。

精密测量部分基于原分光物理体系，针对精密测量物理的前沿工作进行选择性介绍，让学生深入理解精密测量是在现有框架下，利用先进的技术和方法追求高精度，从而检验现有物理学的范围，并试图找出框架的极限，发现新的物理。

工程应用部分将聚焦量子科学与技术的工程应用与相关仪器设备研发，介绍量子科技的应用价值、技术挑战、以及相关科学仪器研发的国际前沿动态。

Quantum information and computing science has made rapid progress recently. This course will introduce the latest developments in the field of quantum information and computation, including topological materials, quantum computation, precision measurement and quantum engineering applications. This course aims at helping students understand the international frontiers of quantum information science, the future trend of quantum computing, the quantum engineering and technical challenges of quantum science and technology revolution. It will try to stimulate students' curiosity and inspire enthusiasm for exploration of quantum science and technology.

The section of topological materials will introduce the basic physics of topological states, including the topological band theory, topological insulators, topological superconductors, topological semimetals, topological quantum computing and the related physical concepts, physical pictures, theoretical models and the corresponding materials. In addition, it will introduce a few topics of the latest research in this field.

The section of quantum computation will focus on the latest developments in several key experimental physics systems of quantum computation， such as superconducting quantum computing, spin magnetic resonance quantum computing, ion trap quantum computing, silicon-based quantum computing, and quantum measurement control theory. For basic courses related to quantum computing, please refer to other

courses offered by the department of physics and Institute of Quantum Science and Engineering.

The part of precision measurement physics will give a selective introduction of the forward progresses in this field, based on atomic, molecular and optical physical systems. Let the students deeply understand precision measurement, which refers to the use of advanced technology and methods to pursue high accuracy under the existing physical framework. Finally, we can test the range of existing physics in a higher precision and try to find out the limit of the frame so as to discover new physics.

The last part will focus on the engineering applications and related instruments research of quantum science and technology, and introduce its applications and technical challenges, as well as the international forefront trends in the R&D of related scientific instruments.

8. 教学方法
Teaching Methods

课堂授课，辅以前沿讲座 Classroom presentation, lecture supplemented

9. 教学内容
Course Contents

Part 1	**《拓扑材料》**Topological Materials
Section 1	拓扑能带理论 Topological band theory
Section 2	一维拓扑物态 One dimensional topological state
Section 3	拓扑绝缘体 Topological insulators
Section 4	三维拓扑绝缘体 Three-dimensional topological insulators
Section 5	拓扑超导体 Topological superconductors
Section 6	拓扑量子计算 Topological quantum computation
Section 7	拓扑半金属 I Topological semimetal I
Section 8	拓扑半金属 II Topological semimetal II
Section 9	高阶拓扑绝缘体 High order topological insulators
Part 2	**《量子计算》** Quantum Computation
Section 1	量子测量控制理论前沿 Frontiers of quantum measurement control theory
Section 2	超导量子计算前沿 I Frontiers of superconducting quantum computation I
Section 3	超导量子计算前沿 II Frontiers of superconducting quantum compuation II
Section 4	自旋磁共振量子计算前沿 Frontiers of spin magnetic resonance quantum computation
Section 5	离子阱量子计算前沿 Frontiers of ion trap quantum computation
Section 6	硅基量子计算前沿 Frontiers of silicon-based quantum computation
Part 3	《精密测量物理》 Precision measurement physics
Section 1	原子分子光物理基础 Fundamentals of atomic, molecular and optical physics
Section 2	原子/离子光钟 Atomic and ionic optical clock
Section 3	超冷量子气体 Ultracold quantum gases
Section 4	原子干涉仪 Atomic interferometer

	Section 5	原子磁力仪 Atomic magnetometer
	Section 6	光量子物理 Quantum optics
	Part 4	**《工程应用》**Engineering Applications
	Section 1	量子计算在大数分解中的应用 Application of quantum computation in decomposition of large numbers
	Section 2	支撑量子科技的先进仪器与技术 Advanced instruments and technologies supporting quantum technology
	Section 3	量子无相互作用测量与量子电镜 Quantum interaction-free measurement and quantum electron microscope
10.	**课程考核** **Course Assessment**	
	考查；平时上课考勤 50%，报告 50% Examination; Attendance: 50%, report: 50% 期末学生围绕课程内容准备一篇图文并茂含参考文献（不少于 3000 字）的综述报告 At the end of the semester, students will prepare a report which including illustration and references according the class (no less than 3000 words).	
11.	**教材及其它参考资料** **Textbook and Supplementary Readings**	
	课堂讲义，授课老师选取的阅读材料 Lecture notes, reading materials selected by the instructor	