课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	**量子材料与量子传感** **Quantum Materials and Quantum Sensing (QMQS)**
2.	**课程性质** **Compulsory/Elective**	选修/Elective
3.	**课程学分/学时** **Course Credit/Hours**	3
4.	**授课语言** **Teaching Language**	英文/English
5.	**授课教师** **Instructor(s)**	Li Baowen, 李保文，Department of Materials Science and Engineering, libw@sustech.edu.cn,
6.	**是否面向本科生开放** **Open to undergraduates or not**	是/Yes，主要面向高年级（三，四年级）本科生/for Junior and Senior Undergraduate students
7.	**先修要求** **Pre-requisites**	（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.） 本科生预修课要求（同时满足以下两点要求）： 1. PHY206-15 量子力学 I 或者 PHY305 量子力学 II（或者 MSE328 材料物理）； 2. PHY321-15 固体物理（或者 MSE203 晶体学）。
8.	**教学目标** **Course Objectives**	
	（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.） 量子材料是量子技术包括量子计算，量子通信和量子传感的基石。量子传感是利用量子叠加原理，量子相干性，量子遂穿和量子纠缠等量子原理来探测如磁场比如单自旋，电场，重力场，质量，加速度等微弱变化。量子传感也为探测量子材料里的奇异性质提供了精准和超灵敏度的测量手段。 这个课程是给学生提供一个关于量子材料与量子传感的最新研究的一个全面的了解。通过这门课的学习，学生不仅能够系统学习量子材料和量子传感的理论基础，而且对这两个方向的的前沿研究有一个深入的了解。学生可以开始进入量子材料和量子传感里自己感兴趣的课题进行研究 . Quantum materials are the basis and building blocks of quantum technology including quantum computing, quantum communication, and quantum sensing.. Quantum sensing utilizes quantum principles such as superposition, coherence, quantum tunnelling, and entanglement to detect very tiny changes in physical quantities such as magnetic field change like single spin, minor changes of gravitational force, mass, acceleration etc. Quantum sensing also provides very accurate and supersensitive tools to detect exotic properties in quantum materials. This course intends to provide students with a comprehensive picture of current research topics in quantum materials and quantum sensing. After this course, the students will not only be able to grasp the relevant theories and methods, but also get a deeper understanding of the current research topics. The student shall be ready to start their research in quantum materials and quantum sensing.	
9.	**教学方法**	

Teaching Methods

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

Lecture (42) + Tutorials (6), Total: 48 hours

10. 教学内容

Course Contents

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

这个课程首先会给学生系统介绍量子材料和传感的理论基础包括量子力学的主要原理（量子相干性，量子叠加原理，量子隧穿，量子纠缠）和固体物理的能带理论。然后会逐个介绍量子材料的主要方向包括超导材料，拓扑材料等，具体内容如下表。为了丰富和加深学生对各个方向的认识，该课程还会安排 6 次客座讲座，邀请国内外在某个特定领域的专家给学生介绍该领域的最新进展。

Section 1	量子力学基础和固体能带理论 Basics of quantum mechanics and solid state physics - Band theory
Section 2	强关联体系：常规超导/Strongly correlated systems: Conventional Superconductor:
Section 3	强关联超导：高温超导/Strongly correlated systems: High-T_c Superconductor
Section 4	T 拓扑超导/opological superconductor
Section 5	拓扑绝缘体，热电材料/Topological Insulator, thermoelectrics
Section 6	巨磁阻和其它磁性材料/GMR and other magnetic materials
Section 7	自旋电子学，自旋流体，斯格米子/Spintronics, Spin Liquid, skyrmion
Section 8	量子霍尔效应/Quantum Hall Effect
Section 9	量子自旋霍尔效应/Quantum Spin Hall Effect
Section 10	量子反常霍尔效应/Quantum Anomalous Hall Effect
Section 11	磁场传感器：核磁共振，NV/ Magnetic Field sensor: NMR, NV,
Section 12	磁场传感器：单自旋，超导量子干涉仪/Magnetic Field sensor: Single spin, SQUID
Section 13	电场传感器：囚禁离子，电荷量子比特 Electric Field Sensor: Trapped ions, charged qubit
Section 14	力/加速度/质量/传感器：干涉仪/ Force/Acceleration/Mass Sensor: Interferometer
Section 15	力/加速度/质量/传感器：光力学，量子声学/Force/Acceleration/Mass Sensor: Optomechanics, quantum phononics
Section 16	量子雷达，鬼成象/Quantum Radar, Ghost Imaging
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11. 课程考核

Course Assessment

（①考核形式 Form of examination；②.分数构成 grading policy；③如面向本科生开放，请注明区分内容。If the course is open to undergraduates, please indicate the difference.）

本课程采用项目报告方式考核。学生可以从任课老师给出的众多研究方向里选出一个自己感兴趣的题目，然后做文献调研，找出有价值的具体的研究课题进行研究。学生需要在期中和期末做两次口头报告和书面报告。最终成绩按照期中 40%（20%口头报告，20%书面报告），和期末 60%（30%口头报告，30%书面报告）来考核。书面报告要求按照 Applied Physics Letter 格式。期中要求 2 页的开题报告， 期末要求 10 页的最终报告

The students' scores will be based on the performance of a selected project:

(1) Midterm presentation (20%), 2-page-double-line report (20%),
(2) Final project presentation (20%) and final report (40%) (10-page, *Applied Physics Letters* style).

12. 教材及其它参考资料
Textbook and Supplementary Readings

"量子材料与量子传感"是崭新的研究方向，本课程是世界首创，因此还没有教科书可以用。 学生主要以上课老师的讲义为线索，广泛阅读任课老师提供的参考文献。 npj Quantum Materials 杂志是学生跟踪了解这个方向的主要来源。

There is no textbooks available. The main references are:

1. F. Giustino et al, "The 2021 Quantum Materials Roadmap", J. Phys. Mater. 3, 042006 (2020).
2. "Quantum Materials for Energy Relevant Technology", http://science.energy.gov/bes/community-resources/reports/
3. Y. Tokura, M. Kawasaki & N. Nagaosa, Emergent functions of quantum materials, Nature Phys. 13, 1056 (2017).
4. C L Degen, "Quantum sensing", Review of Modern Physics 89, 035002 (2017)
5. npj Quantum Materials.
6. 刘俊明-"量子材料"科普微信公众号。