ARAP WITH IMRE RESEARCH AREA: QUANTUM SCIENCE AND TECHNOLOGY

#	A*STAR Researcher	Designation	Email Address	Research Area
1	Prof. Lam Ping Koy	Chief Quantum Scienəst	lampk@imre.a-star.edu.sg	A diamagnetically levitated particle is predicted to be able to perform ultrahigh sensitivity quantum sensing that can go far beyond the standard quantum limit. In this project, we will use a ferromagnetic particle to precess about the magnetic field like atoms precessing at a Larmor frequency under conditions where its intrinsic spin dominates over its rotational angular momentum. Observing atomic precession at a mesoscopic scale requires frictionless levitation to allow free precession, and good magnetic shielding to reduce the orbital angular momentum. Such levitated object is a correlated system of spins that can rapidly reduce quantum uncertainty. The dynamic of such an object can be described by the Landau-Lifshitz-Gilbert equation. The “artificial atom” can be used for developing the next-gen quantum sensors, such as gyroscopes, magnetometers, gravitometer, and accelerators. The “artificial atom” is also useful for quantum information and metrology. For example, coupling Nitrogen- Vacancy (NV) center spin qubits in diamond to the diamagnetically levitated ferromagnetic particle enables single phonon experiments and quantum state preparation of a mesoscopic object. Required background: The project may suit students interested in theoretical modelling and/or experimental work depending on interest and experience. Familiarity with cryostat, SQUID, optical levitation, Paul trap, modeling of hybrid system, and quantum sensing is highly desirable but not necessary.
2	Prof. Lam Ping Koy	Chief Quantum Scientist	lampk@imre.a-star.edu.sg	Generating highly entangled photons is a long-standing goal in quantum optics due to its broad ranging applications. An attractive platform on which to achieve this goal is to use the extremely nonlinear properties of atomically thin 2D crystals. Since the discovery of graphene in 2004, many materials with a stable monolayer form have been found, including the important subclass of transition-metal dichalcogenides (MX_2; M = Mo/W; X = S/Se/Te). These materials are centrosymmetric when in bulk form, but the inversion symmetry is broken when they are thinned down to mono- or few layer thickness. As a result, 2D materials feature an atomic-level dipole that gives rise to extraordinary physical properties including dichroism, ferro and piezo-electricity. Moreover, These monolayers also exhibit enormous second-order susceptibility $\chi(2)$ (per unit length) that can be exploited for efficient nonlinear optical processes. 2D materials can be used for high efficiency spontaneous parametric down-conversion (SPDC). SPDC is a well developed technique in quantum optics to produce entangled photons. This PhD project aims to investigate enhancement techniques to bring SPDC technique down to the atomic scale to enable the generation of highly entangled photons. Required background: Undergraduate physics and mathematics. Familiarity with experimental physics, optics, 2D material research is highly desirable.
3	Prof. Lam Ping Koy	Chief Quantum Scientist	lampk@imre.a-star.edu.sg	the two point sources, ation goes to zero. However, coherent measurement techniques can be used to overcome this limit. By using an ate that is independent of the separation. Ideally, this setup will accurately determine the separation of

6	Prof. Lam Ping Koy	Chief Quantum Scienəst	lampk@imre.a-star.edu.sg	Levitation of macroscopic objects has been demonstrated using superconducting magnetism, electrostatic fields, acoustic pressure, and other physical effects. Perhaps the most well-known application of levitation is the Maglev high-speed train, where levitation is used to eliminate track friction and enable speeds of more than 500 km/h for passenger carrying transport. While levitation is not new, it was only recently thought of as a technology that could be used for probing quantum theory and for precision sensing. Optical tweezers (2018 Nobel prize), for example, use the levitation of nanoparticles for the purpose of studying the quantum opto-mechanical interactions. This PhD project aims to be the first in the world to demonstrate the coherent levitation of a macroscopic object using lasers. By setting up a tripod of high finesse optical resonators, our experiment will operate in the optical spring regime where light inside the optical resonators will provide an amplifiTj/TT41Tf.2275490TD0<0003>Tj1Tf41Tf.22610TDl81e1tati

12	Aaron Lau	Scientist	aaron_lau@imre.a-star.edu.sg	Two-dimensional materials have unique properties for next-generation device applications in areas such as quantum, bio and nano technology. However, realizing quantum nanoelectronics based on these advanced materials requires overcoming two crucial challenges: dielectric integration and contact engineering. Conventional approaches inevitably introduce surface damage that are severe in these atomically thin materials. State-of-the-art solutions remain unsatisfactory in either quality, compatibility or scalability. To overcome these shortcomings, we propose to use liquid metal reaction synthesized ultrathin oxides as gate dielectrics or as protection/seed layers for subsequent dielectric deposition. These ultrathin oxides form as a native oxide skin on liquid metals. They can be printed over large areas onto suitable substrates/materials to form unique heterostructures exciting for various device applications. We have demonstrated the successful printing of ultrathin Ga2O3 onto various substrates and 2D materials to form functional electronic devices. By mixing different elemental metals, eutectic alloys can be created where the ultrathin oxide skin formed on the surface is a mono-elemental oxide for which the reduction of Gibbs free energy is the greatest. Through careful control of the environment such as temperature, pressure and oxygen/moisture content, many different oxides, including HfO2, can be created on the surface of Galinstan, a eutectic alloy made from gallium, indium and tin. There are two work scopes. Students will investigate the oxidation process and characterize the resulting ultrathin films. They will also explore the feasibility of tuning the material properties of the oxide films through post treatments or during the oxide printing process. For example, we have showed that the stoichiometry of Ga2O3 ultrathin oxide films can be changed through oxygen annealing. Mastering control over the properties of these films will widen the potential application areas, e.g., power electronics, solar blind UV detectors, catalysis and water splitting etc. Students will also investigate suitable integration processes for ultrathin oxides with 2D semiconductors and fabricate unique heterostructures. Conventional dielectric growth processes that are scalable and compatible with industrial techniques are unfortunately not compatible with 2D materials. The atomically thin nature and pristine surfaces of 2D materials render them susceptible to [illegible] surfaces (and) [illegible] .5298 0 TD <003> 1 Tj /TT4 1 Tf .22615detectors,

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16	Aravind Anthur	Scientist	aravind_padath_anthur@imre.a-star.edu.sg	The project aims at design, fabrication and characterization of high-quality optical resonators for nonlinear optical applications focusing on the development of on-chip optical parametric oscillators and frequency combs. The optical parametric oscillators and frequency combs are two types of lasers giving single frequency and multiple

23	Lu Ding	Scientist	dingl@imre.a-star.edu.sg	The research in my lab focuses on nanophotonics, nanoplasmonics, resonantors, optoelectronics, etc. I would like to collaborate with groups which have expertise in on-chip integrated quantum information and condensed matter physics.
24	Victor Leong	Scientist	victor_leong@imre.a-star.edu.sg	This project involves the development of non-cryogenic on-chip integrated photonics single-photon detectors. Single-photon detection represent the ultimate sensitivity limit for light detection and integrating such detectors onto photonics circuits would open up a large variety of cutting-edge applications to the field of integrated photonics, including quantum cryptography, photonic computing, AR/VR/metaverse, etc. At the current stage, the projects are focused on refining existing prototype devices, and pushing the development of the devices towards demonstrable single-photon detection capability. Students can work on multiple areas, including device design, device fabrication, setup building/engineering, device characterization, opto-electronic packaging, control electronics, and so on. The students will have a well-rounded exposure and training to various aspects of integrated photonics development, including experimental optics, nanofabrication processes, opto-electronic characterization, electronics, setup automation, and so on.
25	Zhu Di	Scientist	zhu_di@imre.a-star.edu.sg	Our research group focuses on developing devices and materials for photonic quantum information processing. We work on two main areas: (1) integrated quantum and nonlinear photonics on thin-film lithium niobate, including photon-pair generation, quantum frequency conversion, and frequency comb generation; (2) superconducting nanowire single-photon detectors, including developing new materials and readout architectures, as well as integrating them with photonic integrated circuits. We would like to collaborate with groups that are interested in integrated photonics (classical or quantum), nanophotonics, applied superconductivity, or quantum materials/devices.
26	Zhu Di	Scientist	zhu_di@imre.a-star.edu.sg	Implementing practical photonic quantum computation and simulation requires thousands to millions of optical components. Integrated photonics is likely the only route to achieve such scale. However, existing leading integrated photonic platforms, such as silicon and silicon nitride, lack many crucial functionalities required for quantum information processing. To address this problem, we aim to develop an integrated photonic platform based on thin-film lithium niobate, an emerging and versatile material ideally suited for quantum photonics. We will develop on-chip quantum light sources and controllers and leverage them to realize advanced quantum computation protocols.
27	Zhu Di	Scientist	zhu_di@imre.a-star.edu.sg	Superconducting nanowire single-photon detectors (SNSPDs) are currently the best performing single-photon detection technology at infrared wavelengths. They are widely used in quantum information, deep-space communication, and biochemical sensing. However, some applications are posing increasingly demanding requirements on photon detections, such as requiring large arrays, and photon number as well as energy resolution. These are beyond what standard SNSPDs can achieve. In this project, we aim to expand the functionalities of existing SNSPDs by developing new device architectures, exploring new materials, and combining them with novel photonic and microwave structures.