Linsen Li

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Job interest: I have a deep understanding of the whole physical hardware system from the atomic material (quantum physics) to the user interface (system architecture) with enriched design and experiment experience (cleanroom fabrication, digital/analog/radio frequency circuit, and electronics, optical/mechanical/cryogenics engineering). I am interested in joining a hardware team in the role of a **Hardware engineer**; **Hardware Research**; **Electrical Engineer**; **Optics Engineer**; **SoC designer**; **System designer** etc.

Education

- Sep 2019 – Present: **Massachusetts Institute of Technology (MIT)**, Cambridge, MA, USA.
  Department of Electronic Engineering and Computer Science (EECS)
  Ph.D. in Electrical Engineering and Computer Science, 2024 (expected)
  M.S. in Electrical Engineering and Computer Science, Feb 2021. GPA: **5.0/5.0**
- Aug 2015 – Jul 2019: **Tsinghua University (THU)**, Beijing, China.
  Department of Electrical Engineering/Microelectronics (EE)
  B.E. in Microelectronics, Major GPA: **93/100**

Prestigious Prizes and Awards

- **Optics**: Highlighted talk in Conference on Lasers and Electro-Optics (CLEO), May 2022, San Jose, CA, USA **(top 3%)**
- **Quantum**: Quantum Information Science and Engineering Network Triplet Award, 2020-2022. (**78 awards in the USA**)
- **THU**: Tsinghua Presidential Award, Nov 2018 **(Highest honor 10/15000+ undergraduates on THU)**
- **Math**: Meritorious Winner of the American Mathematical Contest in Modeling, Apr 2017**(Top 10% nationwide)**
- **Electronics**: Second-place award in National Undergraduate Electronic Design Contest, Sep 2015 **(Only winner on THU)**
- **Physics**: Gold medal in 16th Asian Physics Olympiad, May 2015 **(as a top 8 student representing China for competition)**
- **Experiment:** The highest score in the experiment portion in the 31st China Physics Olympiad, Nov 2014

Lead Publications and Patents (*Authors contributed equally)

[1]. **Linsen Li,** et al. "Scalable quantum information processing architecture using a programmable array of spin-photon interfaces." In CLEO: QELS_Fundamental Science, pp. FF4J.1. (2022) **(Highlighted)**

[2]. **Linsen Li**, et al. "Field-based design of a resonant dielectric antenna for coherent spin-photon interfaces." Optics Express, 29, 16469-16476 & In CLEO: QELS_Fundamental Science, pp. FW4I.4. (2021)

[3]. **Linsen Li**, et al. "A dielectric antenna for quantum emitter interfaces." Bulletin of the American Physical Society. (2020)

[4]. He Tian*, Yuxing Li*, **Linsen Li***, et al. "Negative capacitance black phosphorus transistors with low SS" IEEE Transactions on electron devices, vol. 66, no. 3, pp. 1579-1583. (2019)

[5]. **Linsen Li**, et al. "First principles study of memory selectors using heterojunctions of 2D layered materials." International Electron Devices Meeting (IEDM), 24.3.1-24.3.4. (2018)

[6]. He Tian*, **Linsen Li***, et al. "High-quality reconfigurable black phosphorus p-n junctions." IEEE Transactions on electron devices, vol. 65, no. 11, pp. 5118-5122. (2018)

[7]. Yutao Li*, Guangyang Gou*, **Linsen Li***, et al. "Millimeter-scale nonlocal photo-sensing based on single-crystal perovskite photodetector." iScience 7, 110–119. (2018)

[8]. **Linsen Li**, et al. "Influence of point defects on optical properties of GaN-based materials by first principle study." Computational Materials Science 129: 49-54. (2017)

[9]. Jiadong Yu, Zhibiao Hao, **Linsen Li**, et al. "Influence of dislocation density on internal quantum efficiency of GaN-based semiconductors." AIP Advances 7, 035321. (2017)

[10]. Keyu Ning, Houfang Liu, **Linsen Li**, et al. "Tailoring perpendicular magnetic anisotropy with graphene oxide membranes." RSC advances 7.83: 52938-52944. (2017)

[11]. **Linsen Li**, Zhibiao Hao. Graphene terahertz emitter and its manufacturing method. Patent Application Number CN201510767570. Filed on Nov. 11, 2015. Granted on Nov. 26, 2018, Assignee: Tsinghua University.

Research and Product Experience (Developed skills in the bullet points)

Quantum computer hardware system (From device to the system)

(Involved roles: **architecture**, **analog/digital/RF SoC design**, **process/electronics/optics/cryogenics engineer**, **system design**)

Sep 2021-Present, Ph.D. work supervised by Prof. Dirk Englund in MIT EECS: [1]

- Built a quantum computer hardware that integrates the advanced qubit (cleanroom fabricated diamond color center) with a large-scale system on chip (SoC) control electronics and optics (diamond / SoC hybrid integration). Which involves:
- **Architecture**: Defined quantum hardware system metric, designed the hardware architecture including the subsystem:
  I. Diamond qubit material with an efficient spin-photon interface using dielectric nanostructure as an antenna ([2], [3])
  II. Foundry chip including the complementary metal-oxide-semiconductor (CMOS) electronics for single-qubit control,
  III. Photonic integrated circuit (PIC) design for photon routing to do programmable remote two-qubit gate.
  IV. Scalable hybrid integration between the diamond qubit material nanostructure with foundry chip (CMOS/PIC)
  V. Subsystem modeling and simulation analysis and detailed components design, fabrication, test, and measurement.
- **(I). Cleanroom fabrication**: fabricated the diamond quantum micro-chiplet (QMC) containing a long spin-coherence qubit
  - Material cleaning: CMOS material, III-V (GaN/GaAs) semiconductor, Diamond
  - Implantation and annealing: Color center implantation and furnace annealing in 1200°C in an optimized sequence
  - Lithography: Photolithography and electron beam lithography with cold development
  - Layout design and visualization: Gdspy, KLayout, Solidworks, AutoCAD, Latex, and Blender
  - Thin film technology: Physical/chemical vapor deposition, atomic layer deposition, molecular beam epitaxy
  - Etching: Dry etch inductively coupled plasma (ICP)/reactive-ion etching (RIE), wet etch with acid and base.
  - Characterization: Scanning/transmission electron microscope, Raman spectrum, X-ray diffraction (XRD),

semiconductor analyzer, atomic force microscopy.

- **(II). SoC design**: Designed the control chip with CMOS electronics (digital, analog, and RF circuit) for single qubit quantum control using the TSMC 0.18um High Voltage (HV) in Cadence, HSpice, and Multisim (Verilog HDL).
    - Digital circuit design: Serial shift register, data selector, communication with serial Peripheral Interface (SPI) interface with external field-programmable gate array (FPGA) control
    - Analog circuit design: HV sample and hold in an array with an external HV source
    - Radio Frequency (RF) circuit design: RF switch, RF Driver with external arbitrary waveform generator (AWG) signal
- **(III). PIC design**: Designed the visible PIC with silicon nitride waveguide for photon routing to do remote two-qubit gate using Sandia national lab visible PIC platform and Applied Nanotool's NanoSOI platform.
    - PIC design in Lumerical: waveguide, taper, edge coupler, ring resonator, antenna, the grating coupler
- **(IV). Packaging**: hybrid integration between diamond QMC and CMOS control chip with electronics and optics packaging
    - Hybrid integration: transfer print with Polydimethylsiloxane (PDMS), pick-and-place (with tungsten probe)
    - Electronics integration: printed circuit board design with Altium, wire bonding, RF packaging
    - Optics integration: fiber array alignment and gluing, 3D printing/machine fab of mechanical components
- **(V). Test and measurement**: built and carried out the cryogenic measurement with electronics and optics
    - Cryogenic: 4K cryostat with optical free space and fiber access; 1.3K dilution fridge with electronics and optics
    - Digital Electronics: Fast/slow logic control with Xilinx FPGA/Arduino microcontroller
    - Analog Electronics: Current-voltage test and Pulse sequence control ~500 MHz
    - RF Electronics: 50GS/s AWG and 10 GHz bandwidth oscilloscope
    - Free space optics: Tunable laser, confocal microscope, spatial light modulator, photoluminescence (PL), spectrometer, high-speed camera, Electron-multiplying charge-coupled devices)
    - Integrated optics: Fiber array, 6-axis mechanical stage, single-photon detector
    - Measurement automation programming: Matlab, python, C, C++, LabVIEW, shell

Modeling and simulation design (From the atom to device)
(Involved roles: **optical components designer**, **device model engineer**, **semiconductor material science engineer**)

M.S. work in MIT EECS, Sep 2019-Feb 2021: [2,3]

- Proposed a field-based design of dielectric antennas interfacing diamond color centers with a 0.4 numerical aperture far-field Gaussian mode. This enables a highly efficient spin-photon interface with 93.2% mode overlap and 421 Purcell Factor.
    - Lumerical antenna structure design with custom physics-based optimization algorithms on MIT server clusters

Visiting scholar work in Stanford EE, Jul 2018-Sep 2018: [5]

- Designed a two-dimensional (2D) tunnel heterojunction with an H-shaped energy barrier, which serves as ultrathin memory selectors with good symmetry, non-linearity, and high endurance. Explored the design space for H-shaped memory using physical modeling and first-principle density functional theory (DFT) quantum transport simulations. Evaluated the H-shaped selector in the one-selector-one-resistor (1S1R) configuration and provided design guidelines for the heterojunction (metal/nL hBN/nL 2D material/nL hBN/metal) design to match with the 1R characteristics.
    - DFT calculation in VASP (Vienna Ab initio Simulation Package) using supercomputer cluster on THU
    - Quantum transport calculation (Current-voltage relation in atom scale device) in QuantumATK with non-equilibrium green's functions formalism (NEGF) using supercomputer cluster in Stanford
    - Semiconductor device modeling with Verilog-A

B.E. work in THU EE, Dec 2015-Jul 2019: [4,6-11]

- Modeled the negative capacitance effect in black phosphorus transistor to explain the experiment I-V curve [4]
- Generated the semiconductor model of reconfigurable black phosphorus p-n junctions that explain the experiment I-V curve [6]
- Put forward a carrier diffusion model explaining millimeter-scale nonlocal photo-sensing effect in single-crystal perovskite [7]
- Investigated the influence of point defects on GaN-based materials by first-principle calculation. I found that vacancy defects increase the effective masses of electrons and holes, consequently no contribution to non-radiative recombination. C-O complex interstitial impurities or Ga interstitial impurities are most likely to lead to yellow luminescence in GaN-based materials. [8]
- Investigated the influence of dislocation defects on GaN-based materials using the physical modeling with the experimental data (Internal quantum efficiency measured by PL and material screw/edge dislocation density measured by XRD) [9]
- Calculated the magnetic anisotropy energy (MAE) by VASP to investigate the perpendicular magnetic anisotropy (PMA) changing of CoFeB thin films by applying a coating of GO membranes on top. Due to changes in the hybridization of 3d orbitals, varying the location of the C atomic layer with Co changes the contribution of the Co–C stacks to PMA. Thus, the large PMA achieved with GO membranes can be attributed to the orbital hybridization of the C and O atoms with the Co orbitals [10]
- Wrote a pattern with a novel device structure using graphene nanoribbon for terahertz wave emission [11]
    - Semiconductor device model in Matlab and Mathematica [4, 6, 7, 9, 11]
    - Device electric field and strain simulation in COMSOL Multiphysics [1, 7]
    - Atomic-scale semiconductor material investigation using VASP and Material Studio for first-principal calculation of
        - Electron band diagram and projected density of states calculation in different atomic structure supercells [8]
        - Electron and hole effective mass changed in the conduction band and valance band [8]
        - Electron density 3D/2D diagram in the atomic structure with atomic defect model [5, 8]
        - Lowest energy atomic structure configurations optimization for material heterojunction or defect [5, 8, 10]
        - Spin-orbit coupling calculation for MAE [10]