

# Energy-efficient Ferroelectric Spin-Orbit logic

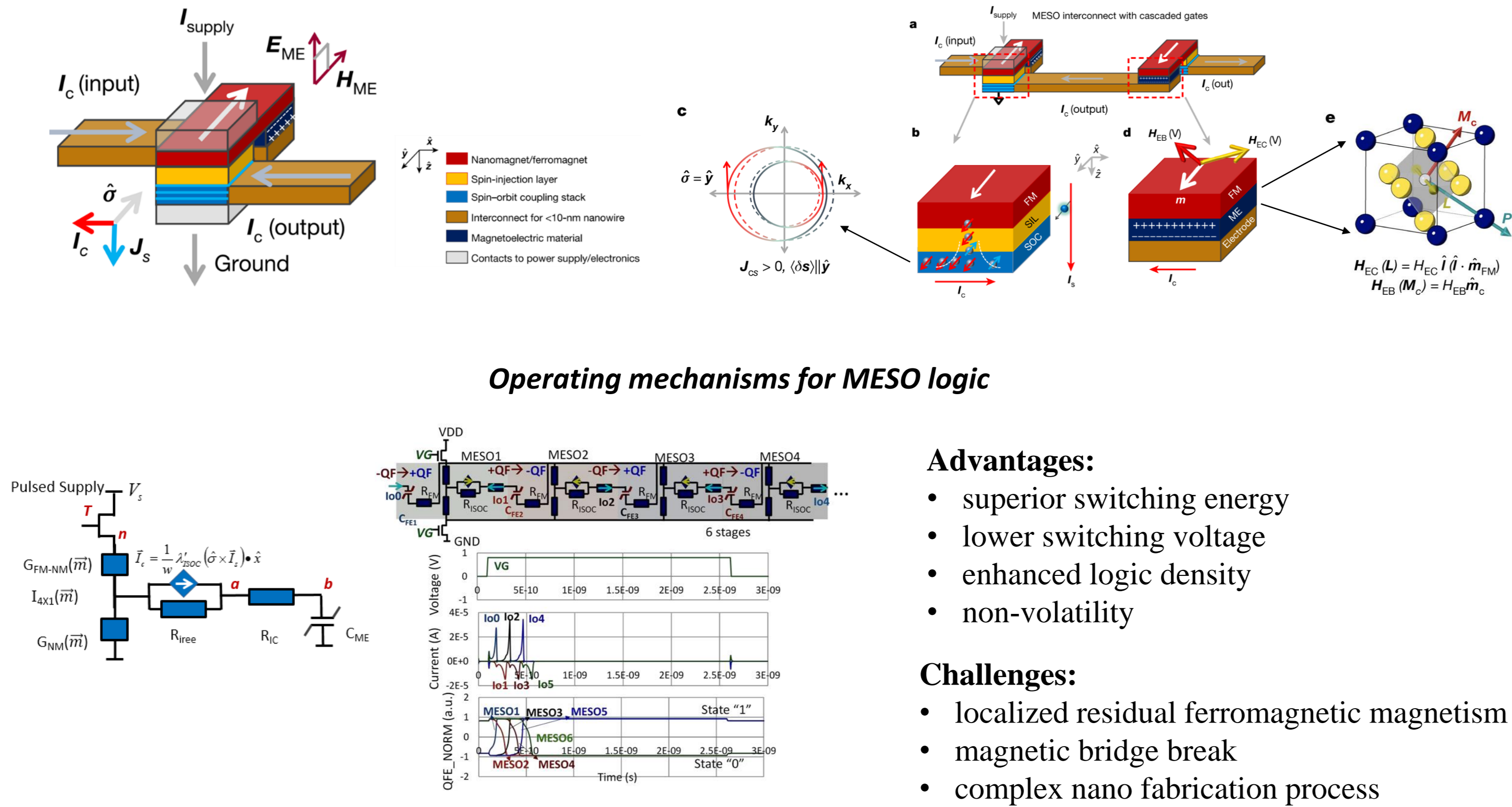
Wentao Liao<sup>1,2</sup>, Zhifei Zhu<sup>1,2</sup>, Xiaolan Tao<sup>1,2</sup>, Yinyan Zhu<sup>1,\*</sup>, and Jian Shen<sup>1,2,\*</sup>

1 State Key Laboratory of Surface Physics and Institute for Nanoelectronic Devices and Quantum Computing, Fudan University, Shanghai 200433, China

2 Department of Physics, Fudan University, Shanghai 200433, China



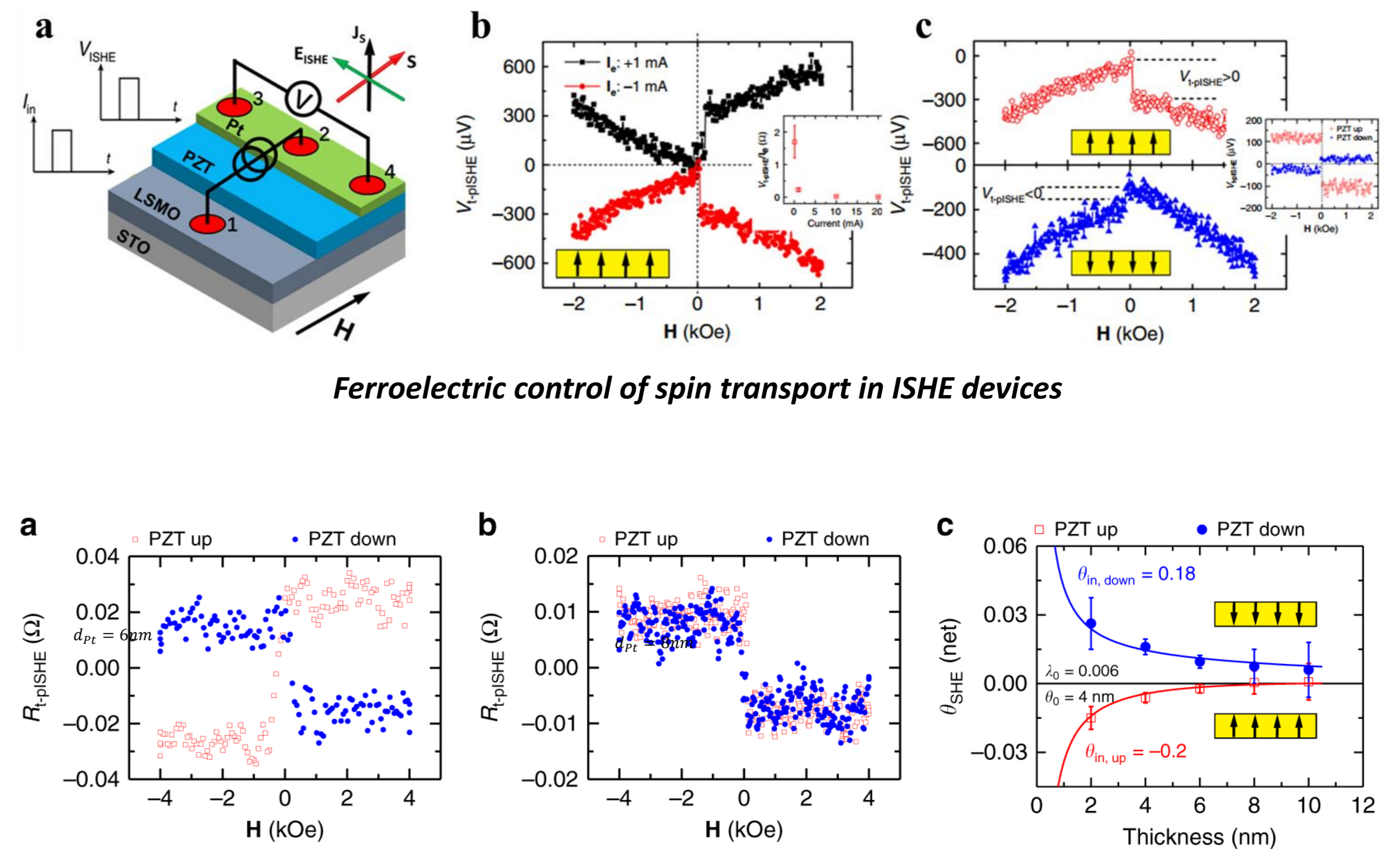
## Magnetoelectric spin-orbit (MESO) device



Circuit schematics of single and cascaded 6-stage Vector Spin Equivalent Model for MESO Logic device

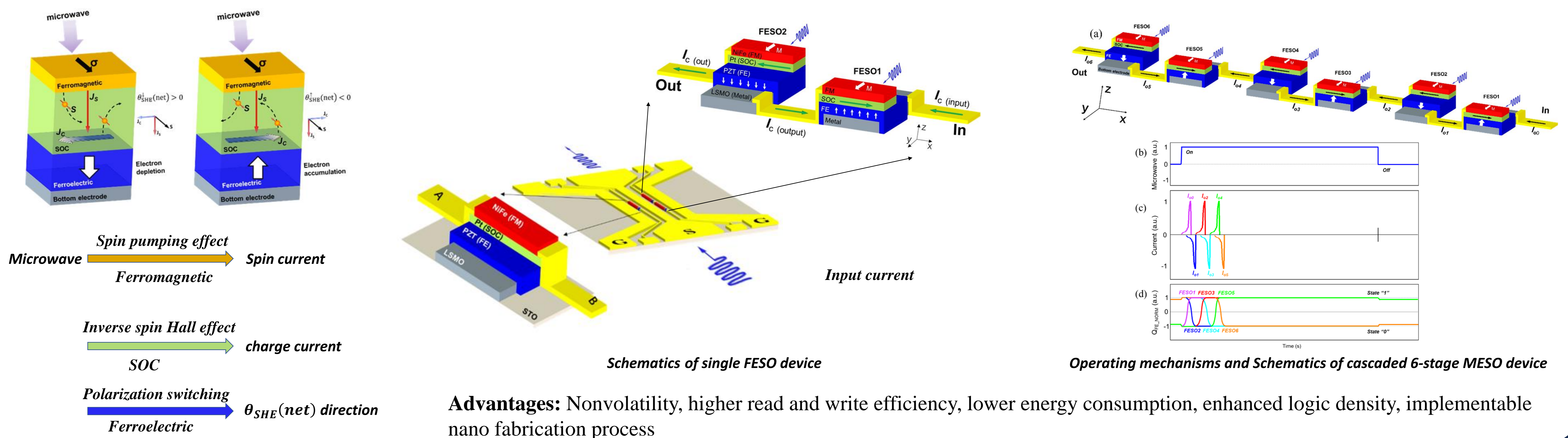
Manipatruni, Sasikanth, et al. Nature 565, 35–42(2019)

## Ferroelectric tuning of interfacial spin-orbit coupling

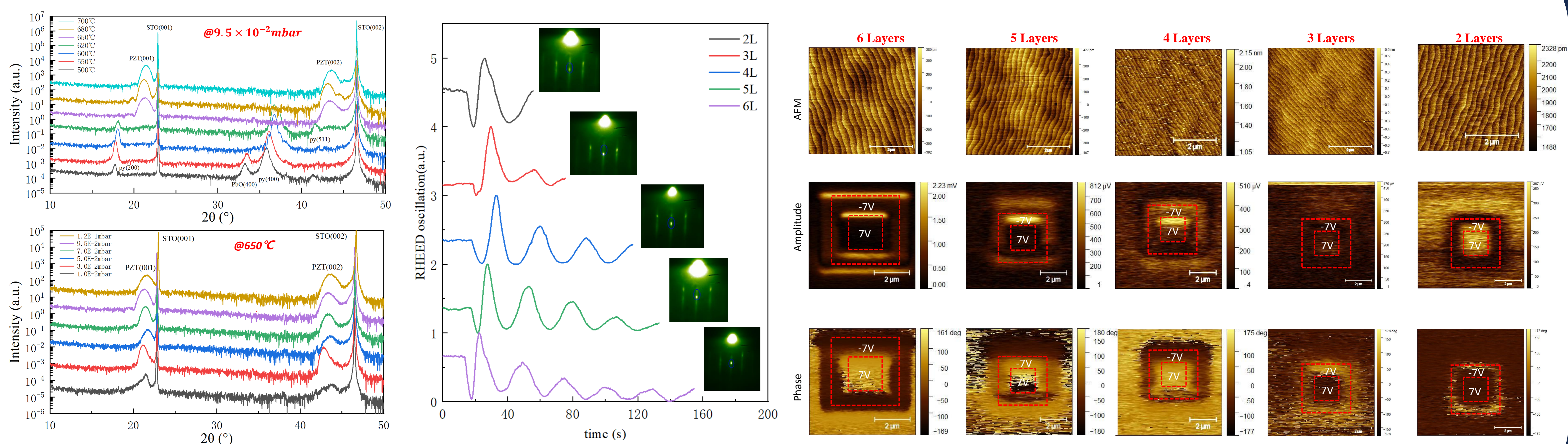


Shen, Jian, et al. Nat. Commun. 11, 2627 (2020)

## Design of FESO (Ferroelectric Spin-Orbit) device



## Structure and Ferroelectricity of ultrathin PZT film



## Conclusion

- Propose a scalable spintronic logic device operates via spin-orbit transduction Spin pumping and inverse spin
- Hall effect are used to efficiently convert spin currents into charge currents
- Perovskite phase PZT growth is sensitivity to temperature and oxygen pressure.
- FESO device consist of ferroelectric/spin-orbit coupling/ferromagnetic (PZT/Pt/NiFe) heterostructure.
- Net spin Hall angle is active controlled by the ferroelectric polarization.
- PZT films keep the ferroelectricity even down to the thickness of 2 unit cells.