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Transition metal dichalcogenide dimer nano-antennas with ultra-small gaps

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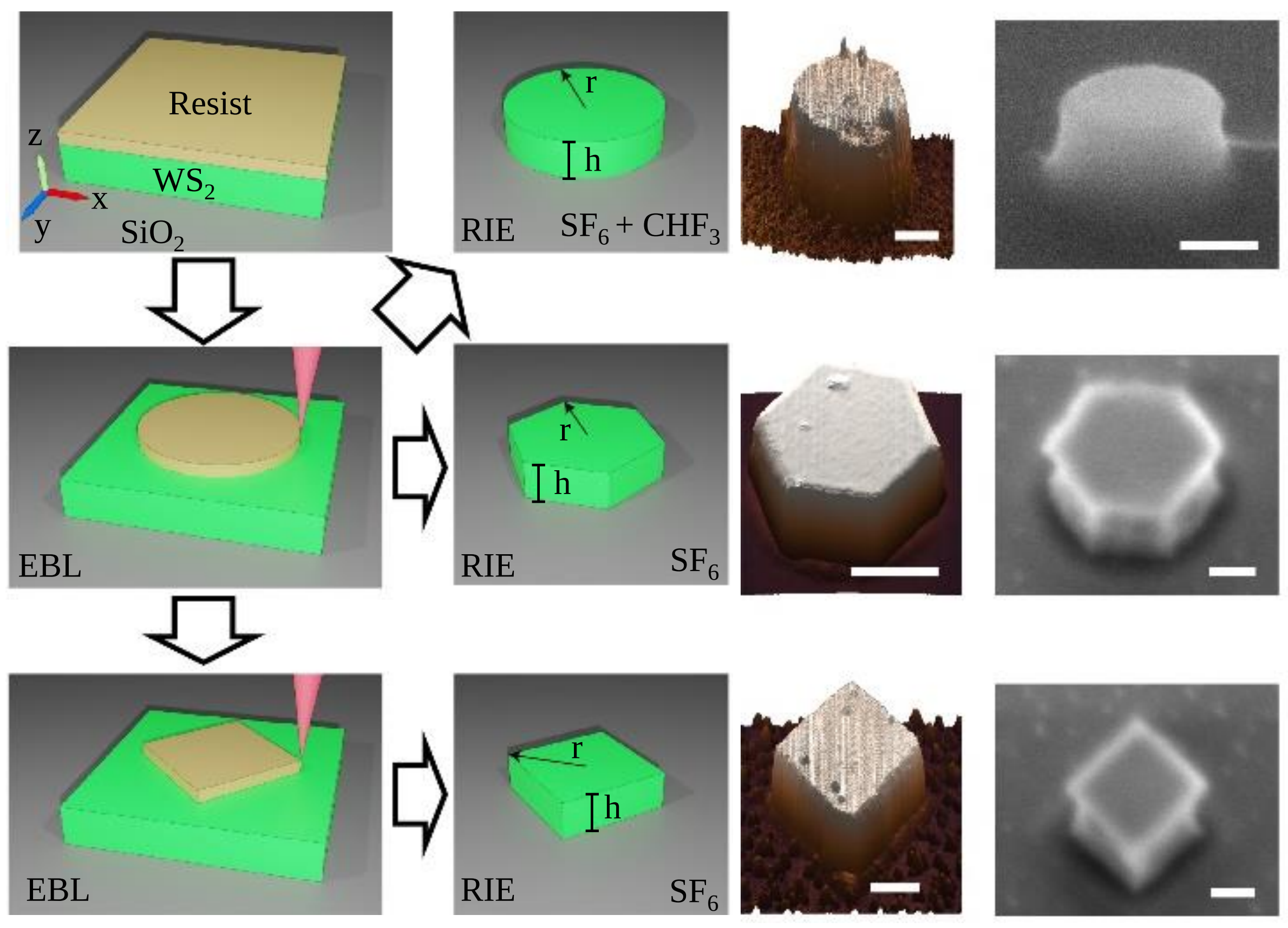
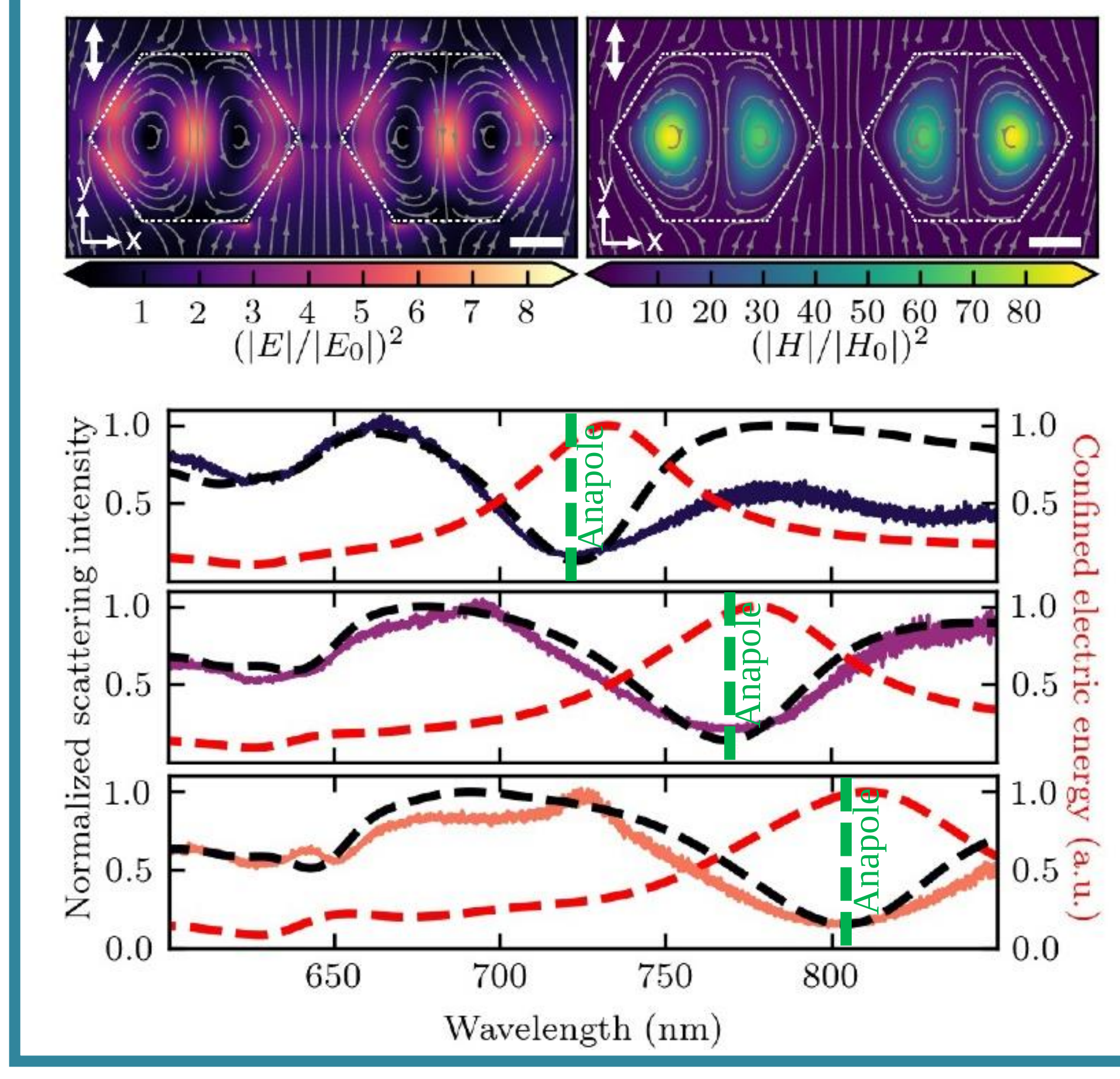
1. Fabrication of WS_2 nano-antennas



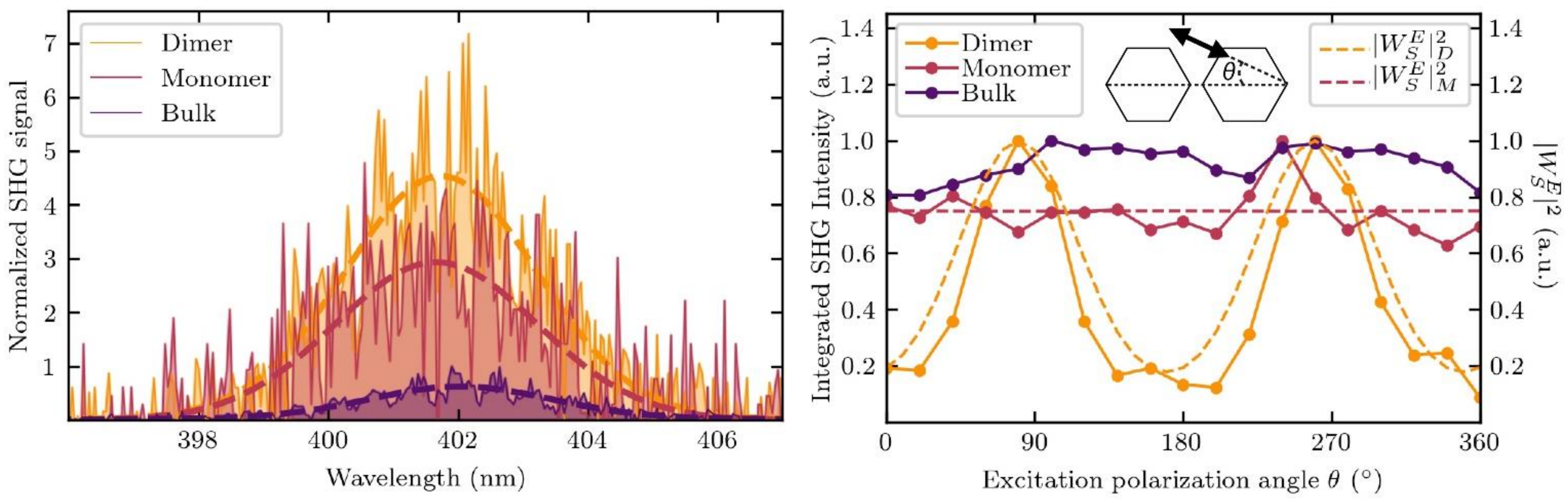
- We fabricate WS_2 nano-antennas using electron beam lithography and reactive ion etching.
- By tuning the etching recipe, we fabricate circular, hexagonal or square nano-pillars and nano-antennas.

2, Photonic resonances of nano-antennas



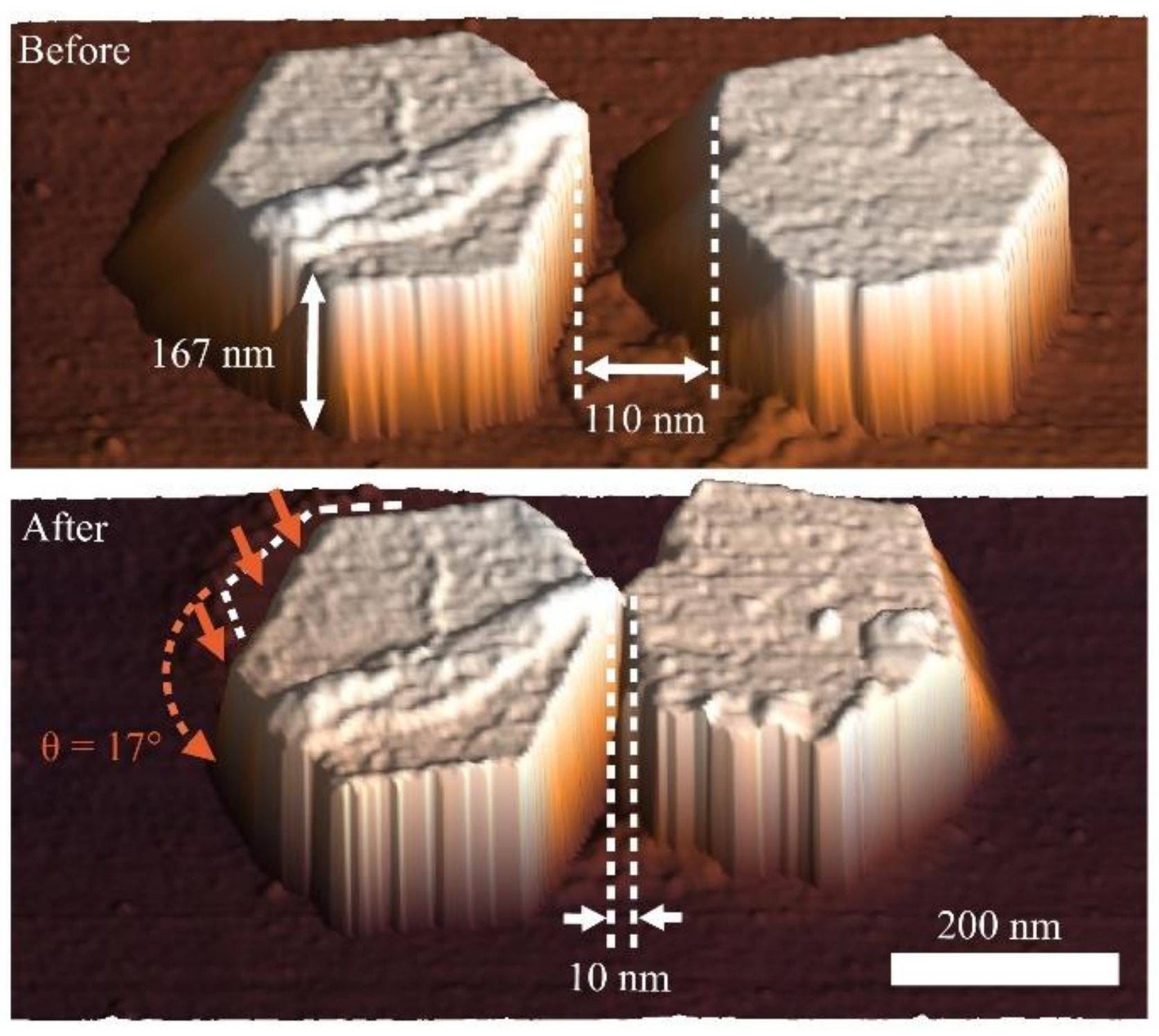
- We fabricate two hexagonal nano-antennas in close proximity (<200 nm) as a dimer nano-antenna.
- Similar to individual WS_2 nano-disks [1], dimer nano-antennas host Mie resonances.
- The destructive interference between dipole and toroidal resonances form an energy-confining anapole mode [2].

3. Second harmonic generation enhancement



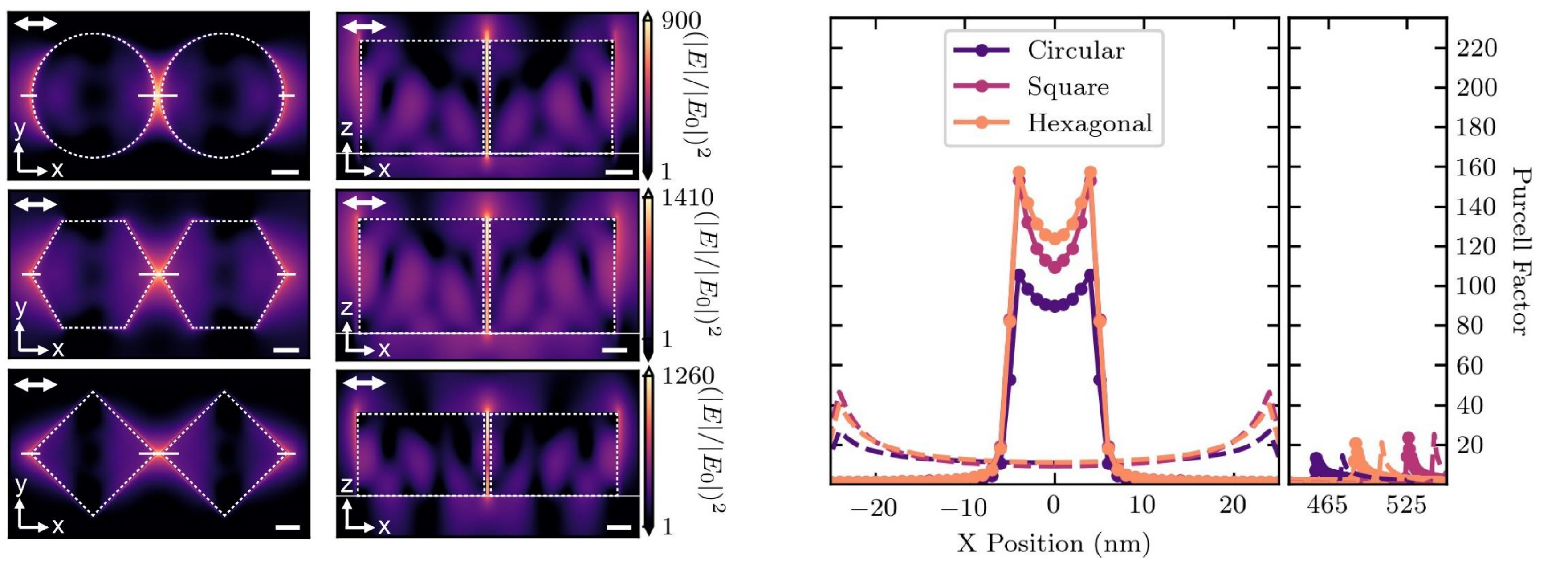
- Dimer and monomer WS_2 nano-antennas yield second harmonic generation (SHG) enhancement [3].
- Dimer nano-antennas result in a 1.6 times larger SHG enhancement than monomers and produce a polarization-dependent SHG signal.

4, Atomic force microscopy repositioning



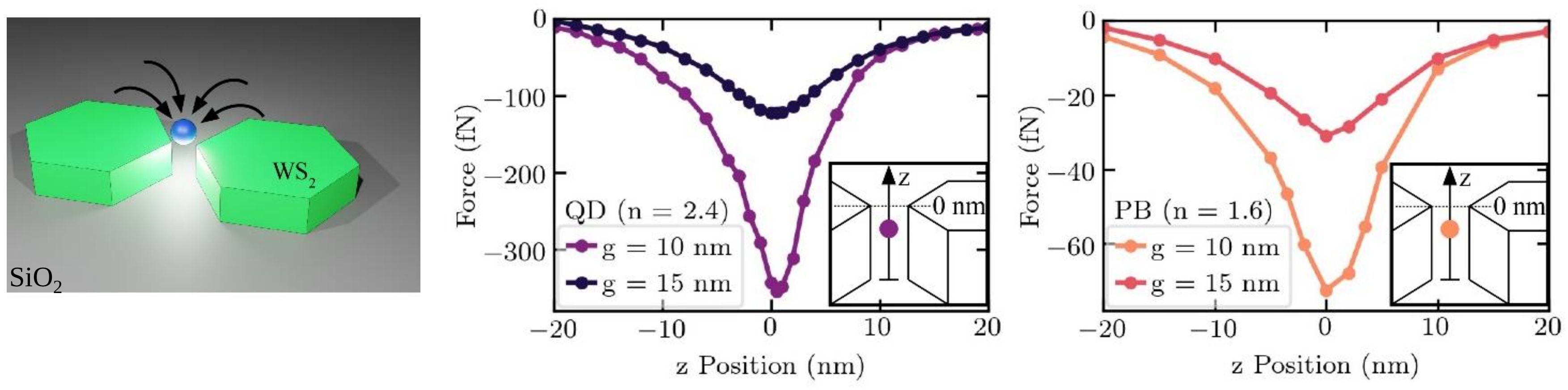
- Precise translation and rotation of individual nano-pillars in a dimer nano-antenna can be achieved with atomic force microscopy (AFM) owing to weak van-der-Waals forces intrinsic to TMDs.
- Separation gaps as low as 10 nm are attainable.
- Such small gaps allow for large electric field intensities within hotspots formed in the dimer gap [4].

5. Electric field and Purcell enhancement of emission



- Simulations of nano-antennas with ultra-small gaps (10 nm) yield electric field intensity enhancements of > 10^3 as well as Purcell factors as high as 157 for a single photon emitter positioned at the hotspots of a hexagonal dimer nano-antenna.

6, Optical trapping



- Optical trapping force simulations for dimers with ultra-small gaps result in attractive forces as high as 353 fN for colloidal quantum dots and 73 for protein-like, polystyrene beads.
- Compared to recent reports of dielectric nano-antenna optical trapping [5,6], WS_2 dimers yield larger forces by more than an order of magnitude.

7, Conclusion

- The large refractive index and transparency window in the visible as well as the compatibility to a variety of substrates establish TMDs as an attractive material for fabrication of nano-photonic structures and devices.
- The large Purcell enhancements and optical trapping forces we calculate for WS_2 dimer nano-antennas with ultra-small gaps highlight the necessity for AFM repositioning which is possible due to the weak van-der-Waals adhesion to the substrate.

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