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Second harmonic generation in two-dimensional materials

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Two-dimensional (2D) materials, such as graphene, TMDs and gallium mono-chalcogenides, showing great potentials to complement silicon electronics and optoelectronics, have been widely reported for promising optoelectronic devices including photodetectors, modulator, and light emitters. In virtue of shapeable electronic structures, 2D materials also occupy various distinct second harmonic generation (SHG) characteristics, including extraordinarily high efficiency (three orders of magnitude higher than other common nonlinear crystals), layer-dependence, and electrical tunability. If the extraordinary SHGs were emploited further, 2D d h ld optoelectronic applications might be greatly extended into nonlinear regimes for coherent light source generations, image processings, ultrafast laser engineerings, etc. In this talk, we would report our two recent work about SHG in 2D materials.

First, we report the layer-dependent second harmonic generation (SHG) in atomic layered ReS2. Different from most of the atomically thin ransition metal dichalcogenides, e.g., MoS2 and WS2, monolayer ReS2 has no SHG, and strong SHG can only be obtained from a even- layered ReS2 flake. From a bilayer ReS2 flake, we obtain an effective second order nonlinear susceptibilities of 900 pm/V, which is the highest value reported in 2D materials at the telecom-band.

Second, We demonstrate the first achievement of continuous-wave (CW) pumped second harmonic generation (SHG) in few- and mono-layer gallium selenide (GaSe) flakes, which are coated on silicon photonic crystal (PC) cavities. Because of ultrahigh second order nonlinearity of the two-dimensional (2D) GaSe and localized resonant mode in the PC cavity, VKJ pump power is greatly reduced to microwatts. In a nine-layer GaSe coated PC cavity, while the optical power inside the GaSe flake is only 1.5% of that in the silicon PC slab, the SHG in GaSe is more than 650 times stronger than the third harmonic generation in silicon slab, indicating 2D J dVh great potentials to strengthen nonlinear processes in silicon photonics. Our study opens up a new view to expand 2D d h ld optoelectronic applications in nonlinear regime and chip-integrated active devices.

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Photograph by Xiaodong Hu