Lasing of CdSe/SiO_2 Nanocables Synthesized by the Facile Chemical Vapor Deposition Method

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Supporting Information

Cleaving the nanocables by fiber taper

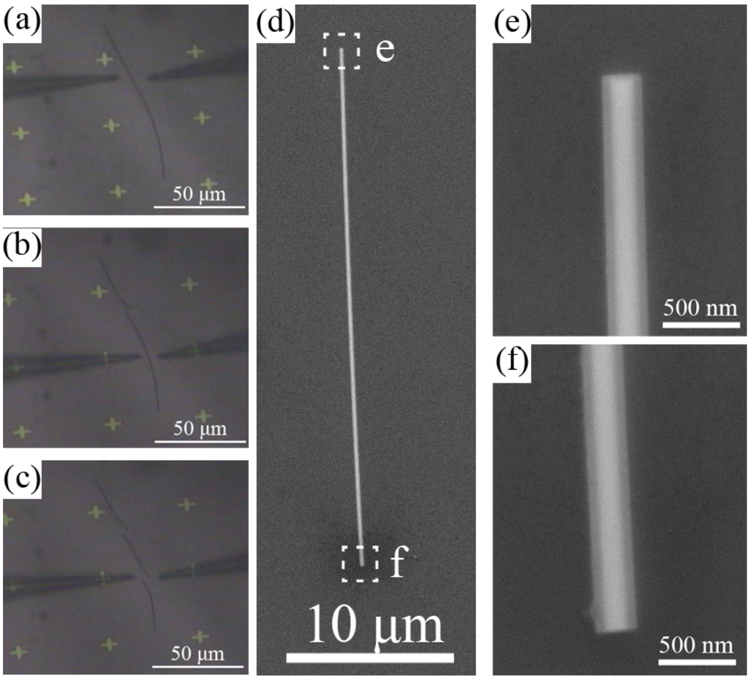

Figure S1. (a-c) Processes of cleaving the nanocables by fiber taper probes under an optical microscope. (d) A typical FESEM image of a cleaved nanocable. (e-f) High-magnification FESEM images of the well-defined facets of the cleaved nanocable.

Lasing threshold vs core diameter and shell thickness

In order to reveal the lasing threshold vs core diameter and shell thickness relations, we use the finite element method to simulate the field distribution inside and outside the nanocable. Figure S2a shows the confined fraction of the HE_{11} mode intensity inside the CdSe core as a function of the core diameter. In this simulation, the shell thickness is fixed to be 70 nm. We can see that the confined fraction increases with the core diameter. For example, the confined fraction of the HE_{11} mode intensity increases from 29.0% for core diameter of 150 nm to 90.0% for core diameter of 250 nm. Figure S2b show the confined fraction of the HE_{11} mode intensity inside the CdSe core as a function of the shell thickness (the core diameter is fixed to be 220 nm). Here, the confined fraction fluctuates within 5% as the shell thicknesses varying from 0 to 100 nm, indicating that the lasing threshold it is less sensitive with the shell thickness.

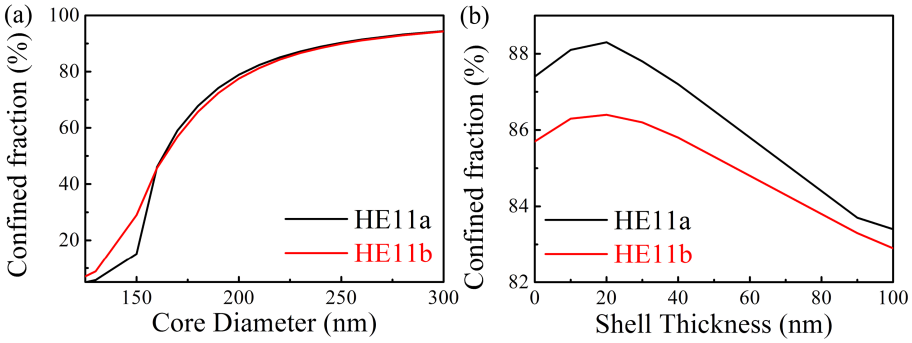

Figure S2. Confined fraction of the HE_{11} mode intensity inside the CdSe core as a function of core diameter (the shell thickness is fixed to be ~70 nm) (a) and shell thickness (the core diameter is fixed to be ~220 nm) (b). Note that due to the break of the cylindrical symmetry, here the HE_{11} modes split into two possibilities, which are labeled as HE_{11a} and HE_{11b}.

TEM images of the nanocables with different sizes

Figure S3a-d shows the TEM images of the nanocables with different sizes. The cores of the nanocables have a wide range form 50 to 350 nm and the sheaths have a range from 40 to 100 nm.

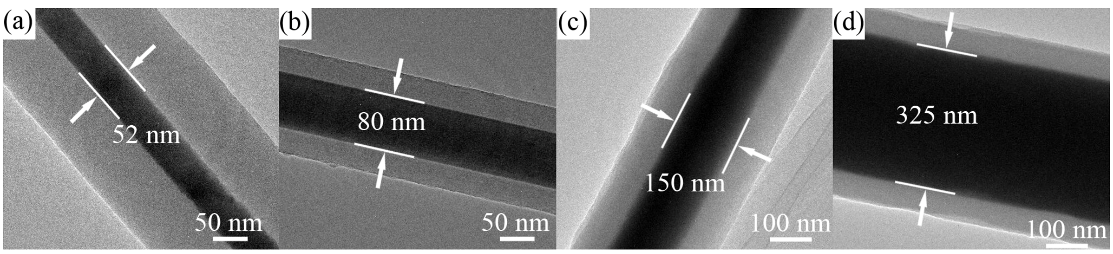

Figure S3. The TEM images of the nanocables with different sizes.

PL spectrum of a CdSe/SiO_2 nanocable with core diameter < 150 nm

We have provided the PL spectrum of a CdSe/SiO_2 nanocable with core diameter of ~135 nm (< 150 nm) under the pumping laser intensity as high as 200 μJ/cm^2 (Figure S4). In this case, no lasing behavior was observed before the nanocable was burned by the pumping laser with intensity higher than 200 μJ/cm^2.

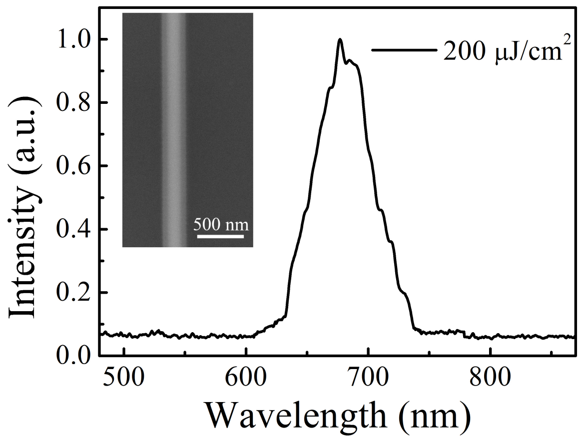

Figure S4. The PL spectrum from a nanocable on a SiO_2 substrate. The pumping laser intensity is 200 μJ/cm^2. Inset: a high-magnification FESEM image of the measured nanocable, which has a core diameter of ~135 nm, a shell thickness of ~68 nm, and a length of ~45 μm).

Material- and geometry- dependent of minimum core diameter for lasing

We think that the minimum core diameter required for lasing is both material- and geometry- dependent. For example, the gain threshold for CdSe nanowire (NW) should be higher than that for ZnO NW, because the near-bandedge emission wavelength for CdSe (~709 nm) is larger than that for ZnO (~385 nm).[S1] Besides, compared to the free-standing nanocable in air, the nancable lying on a substrate will render more leakage of photonic mode, because the refraction index of substrate usually is higher than that of the air. In order to manifest this more clearly, we have performed some theoretical simulation. The calculated electric field ($\left|E^2\right|$) distributions of the fundamental mode (HE_{11}) of a free-standing ZnO NW and CdSe NW with identical sizes (the diameter is 150 nm) in air are shown in Figure S5a and Figure S5b, respectively. The result shows that the fraction of the mode intensity inside the gain material NW decreases from ~89.9% for the ZnO NW to ~15.5% for the CdSe NW, which results from the difference of the light wavelengths inside the CdSe (~709 nm) and ZnO (~385 nm) NWs. The calculated electric field ($\left|E^2\right|$) distribution of the fundamental mode (HE_{11}) of a free-standing CdSe/SiO_2 nanocable in air and that of the CdSe/SiO_2 nanocable lying on a SiO_2 substrate are shown in Figure S5c and Figure S5d, respectively. The core diameter and shell thickness for the nanocable are assumed to be about 150 nm and 70 nm, respectively, in both cases. The result shows that the fraction of the mode intensity inside the CdSe core decreases from ~42.3% for the free-standing nanocable to ~29.0% for the nanocable lying on a SiO_2 substrate. This results from an extra mode leakage into the substrate for the nanocable-on-substrate geometry, which is up to 26.7% in this case. All these results indicate that the minimum diameter of 1D gain material for lasing is material- and geometry- dependent.

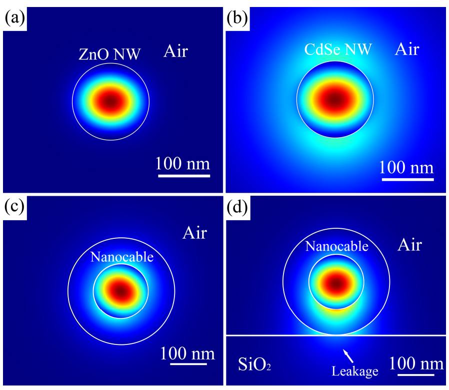

Figure S5. Calculated electric field ($\left|E^2\right|$) distribution of the HE_{11} mode of the cylindrically symmetric case for a free-standing ZnO NW (a) and a free-standing CdSe NW (b) in air. The diameters of both NWs are150 nm. Calculated electric field ($\left|E^2\right|$) distribution of the HE_{11} mode of a free-standing nanocable in air (c) and lying on a SiO_2 substrate (d). The core diameter and shell thickness of the nanocable are 150 nm and 70 nm, respectively.

References

(S1) M. A. Zimmler, J. M. Bao, F. Capasso, S. Müller, C. Ronning, *Appl. Phys. Lett.*, 2008, **93**, 051101.