Electronic Supplementary Material (ESI) for Nanoscale Horizons.

Supplementary Information for "Indirect bandgap $MoSe_2$ resonators for light-emitting nanophotonics"

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Figure 1S demonstrates PL spectra of cavities with large diameters (3, 5, and 10 um). As one can see, the 3 um cavity demonstrates some features related to WGM resonance.

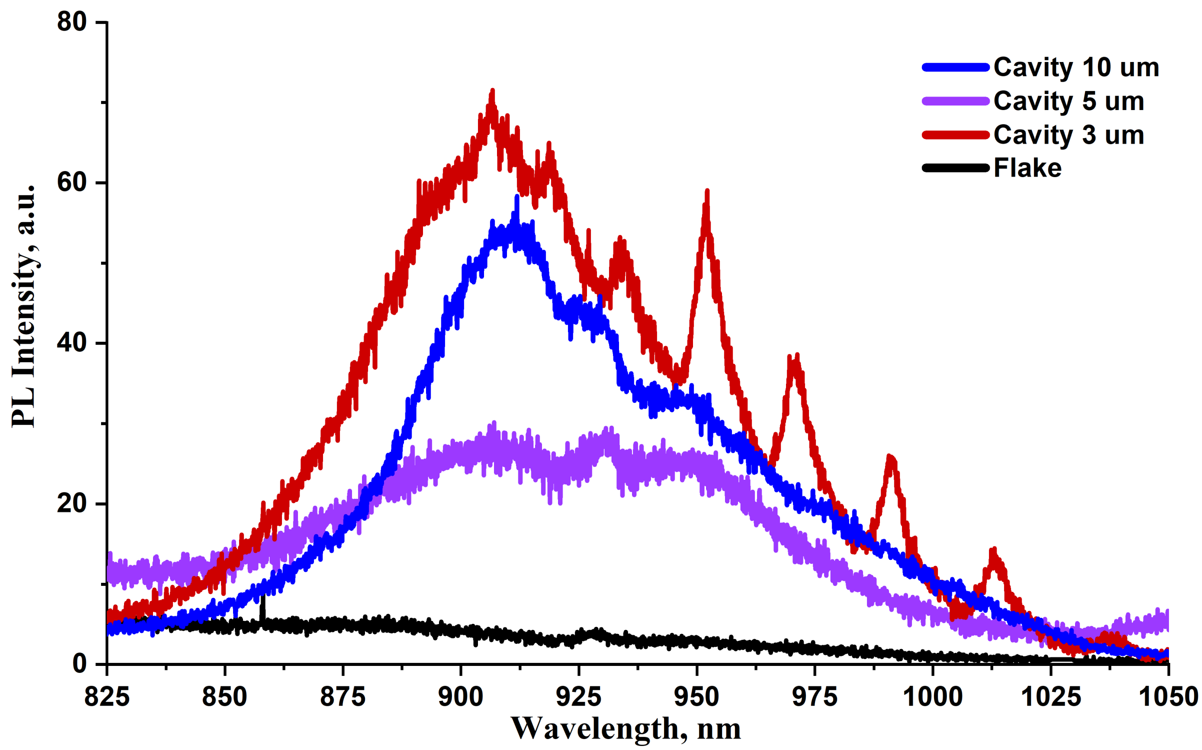

Figure 1: PL spectra of cavities of various diameters.

However, these peaks are significantly weaker than in the 2.2 um cavity case, and the flake-like PL peak dominates (see Figure 1S, red curve). In the case of 5 and 10 um resonators, even weak WGM-like features disappear, and only unmodified flake photoluminescence remains in spectra (see Figure 1S, purple and blue curves).

Figure 2S shows the dependence of the maximum PL intensity and enhancement factor on the cavity diameter.

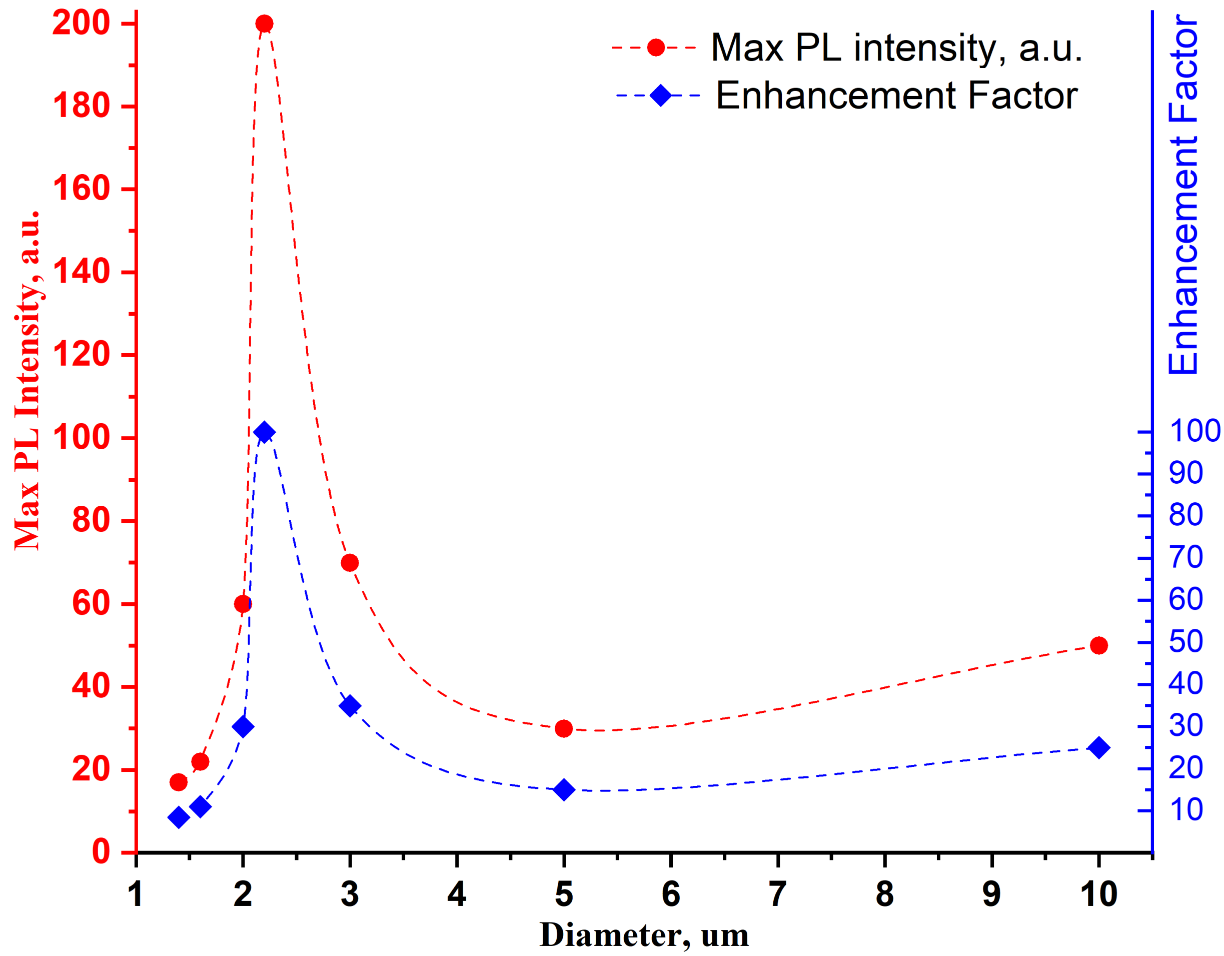

Figure 2: Dependence of the maximum PL intensity on the cavity diameter.

Photoluminescence lifetime measurements were performed with a picosecond pulsed laser diode head (PicoQuant LDH-FA 532 nm) in combination with a single-photon avalanche diode (MPD PDM PD-100-CTC-FC) integrated with a micro-PL setup based on a slit spectrometer coupled to a liquid-nitrogen-cooled imaging CCD camera (Princeton Instruments SP2500+PyLoN). It allowed us to use a spectrometer as a monochromator and make time-resolved PL measurements for selected wavelengths. Figure 3S shows the instrument response function (IRF) of the experimental setup and PL decay curves for the bulk flake and the microcavity with 2.2 um diameter, which were measured at 966 nm (see Fig. 4a). Time constants for the short lifetime region of curves are $t_1^{Bulk} = 37\pm2$ ps, $t_1^{Cavity} = 37\pm2$ ps, $t_1^{IRF} = 36\pm2$ ps that is in good agreement with FWHM values, the main difference of measured spectra are observed for time constants associated with a long lifetime region: $t_2^{Bulk} = 345\pm10$ ps, $t_2^{Cavity} = 318\pm2$ ps, t_2^{IRF} =311 ±10 ps.

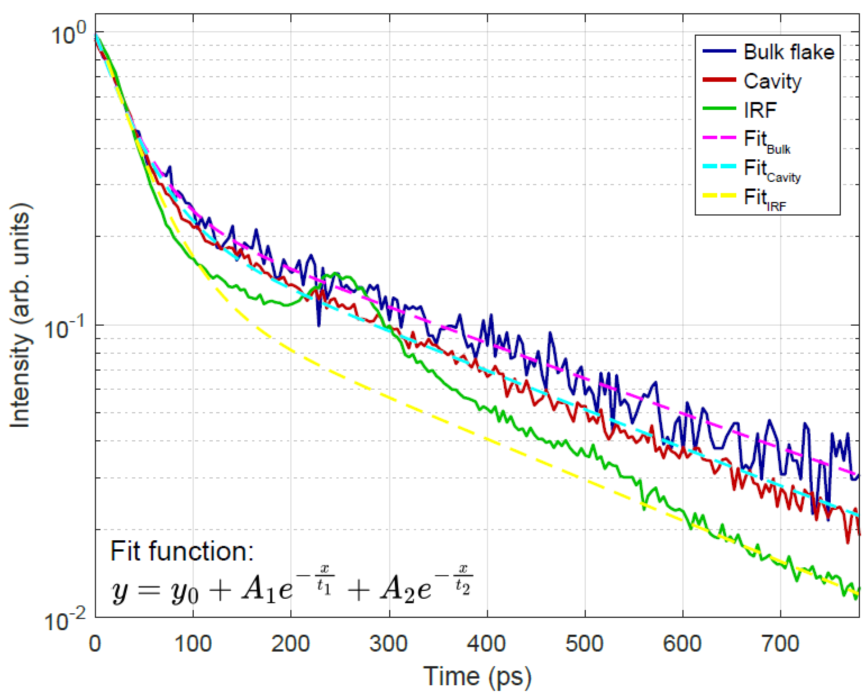

Figure 3: Time-resolved PL of the bulk flake (blue curve) and cavity (red curve). IRF function is presented as a green curve. The second peak at 250 ps is associated with a parasitic reflection in a micro-PL setup. The dashed lines show the approximation of experimental data with a two-phase exponential decay function.

Figure 4S shows a comparison of the PL intensity of a $MoSe_2$ monolayer on SiO_2 and 70-nm-thick $MoSe_2$ resonator on Au.

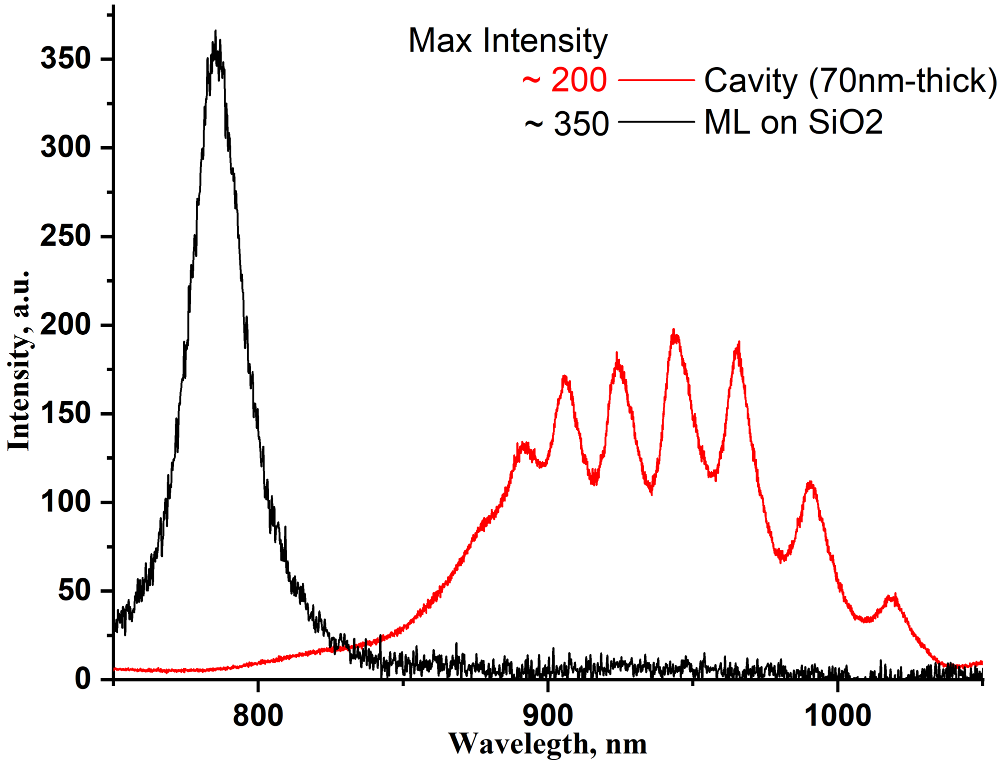

Figure 4: Comparison of the PL intensity of a $MoSe_2$ monolayer on SiO_2 and 70-nm-thick resonator on Au.

It should be mentioned that the direct comparison of signals measured from the monolayer and WGM cavity is tricky. To measure the μ-PL of our structures, we used Olympus MPLN100× objective lens (NA = 0.9) with a spot size of less than 1 um. As we mentioned in the manuscript, WGM resonators do not emit vertically, but defects on the surface can help to output the light. Thus, measuring the PL intensity of a WGM cavity having a significantly larger diameter than a light spot of the objective, we collect only some part of the real PL of the cavity. The rest of the signal is distributed across the cavity and emitted through other defects and side walls. On the other hand, measuring the PL intensity of the monolayer, we collect the whole signal. Despite this, the intensity of the cavity with a diameter of 2.2 μm is about 60% of the monolayer.