the lasing action in the ZnO NRAs. The decrease of threshold for lasing in the annealed sample could be attributed to the improvement in crystal structure and oxide phases of the ZnO nanorods by annealing. As the pump intensity increases, the intensity of discrete peaks increases dramatically together with the appearance of more lasing peaks.

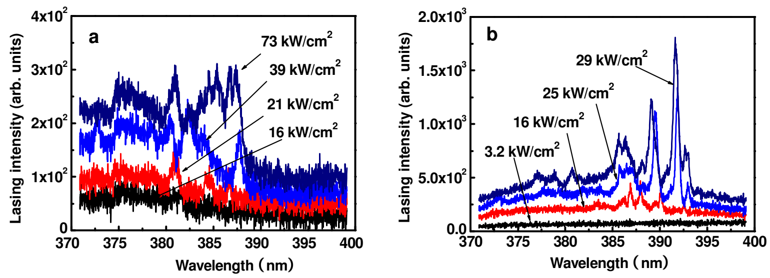


Fig. 5. Spontaneous and lasing emission spectra obtained at different pump intensities taken from (a) as-grown and (b) annealed ZnO nanorod arrays.

It is worthwhile noting that the linewidths of the sharp peaks are very narrow (FWHM ~0.6 nm) and the spacings between the adjacent sharp peaks are not the same, which resembles a spectrum resulting from a random lasing process. In nanostructured ZnO materials, ZnO can provide optical amplification as a gain medium and light forms close loops by multiple scattering. These loops can serve as laser resonators. For a ZnO nanorod, it can act both as a laser resonator for guided modes and as a gain medium for stimulated emission [22]. The lasing emission wavelength is defined by the guided modes of the nanorod. In our case, however, the ZnO NRA is an ensemble of nearly aligned ZnO nanorods with different sizes. The discrete peaks of the emission from the sample represent a superposition of lasing modes from different ZnO nanorods, rather than the lasing due to photon coherent scattering. The emission wavelengths of lasing modes of each nanorod in the ensemble do not coincide exactly with each other. Therefore, the emitted lasing emission on the whole looks much like as random lasing rather than well defined one. It is also worth mentioning that the observed threshold is much lower than the early reported value for the ZnO nanorod arrays prepared by pulsed laser deposition [7]. We have noticed that in that case, the nanorods were irregular with different shapes and sizes, and grew densely with their diameters gradually decreasing from the bottom to the tip. In the present work, in contrast, highly aligned hexagonal ZnO nanorods were fabricated with well-faceted surfaces both at the ends and sides. ZnO nanorods with more perfect shape are more effective acting as resonators and gain mediums for stimulated emission, and hence low-threshold lasing can be expected.

## 4. Conclusions

We have demonstrated low-threshold lasing in ZnO nanorod arrays fabricated hydrothermally on nanocrystalline ZnO seeded Si. The nanorods are vertically aligned with typical diameters of 80 to120 nm and a length of 1.5 μm and are nanocrystalline with wurtzite structure and *c*-axis orientation. At room temperature, the ZnO NRAs exhibit good behaviors on UV luminescence with CW light excitation and UV lasing emission with 30 ps optical pumping. Annealing in $N_2$ results in an improvement in ZnO crystallinity and an enhancement in light emission. The lasing threshold power density of the annealed ZnO NRAs is ~16 kW/cm$^2$. The random-lasing-like emission is a superposition of guided lasing modes from an ensemble consisting of ZnO nanorods with different sizes. The remarkable performance on UV emission is attributed to the oriented alignment of ZnO nanorods with high crystalline quality.

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