Low Threshold Coherently Coupled Organic VCSEL

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Here we report observation of extremely low threshold lasing in organic VCSELs when the excitons are coherently coupled non-radiatively to each other. Non-radiative coupling between excitons can enhance the emission cross-section of a gain material and lead to laser action at considerably lower excitation densities. The coupling strength associated with the excitonic interaction is proportional to the number of excited molecules at any given time; hence the effect necessitates creating the exciton population quickly relative to the excited state decay time. This phenomenon is often referred to as superradiance. In organic semiconductor VCSELs, this effect leads to a 95% reduction in laser threshold when sub-psec non-resonant excitation is utilized to create the exciton population, instead of a longer nsec duration pump pulse. The VCSELs consist of a thermally evaporated gain layer composed of the laser dye DCM doped (2.5 % v/v) into an Alq_3 host matrix, which is situated between a metal mirror and a dielectric Bragg reflector (DBR). In VCSELs where the gain layer is "$\lambda/2n$ thick", i.e. 156.7 nm, an extremely low threshold of 4.9 $\mu J/cm^2$ is observed. Moreover, this is the first time lasing from organics has been reported in a metal/DBR half-wavelength thick microcavity, despite the quality factor for such a microcavity being a rather modest $Q < 200$. Lasing is confirmed by supra-linear input-output power dependence and by spectral and spatial line narrowing above threshold. Moreover, when the optical excitation is polarized, the emission from the device above threshold strongly follows the polarization of the pump light. All prior demonstrations of laser action in solid state organic VCSEL structures have utilized either gain layers of at least 3 times the thickness or have relied on higher finesse all dielectric microcavities. The observed laser threshold of 4.9 $\mu J/cm^2$ in the half-wavelength thick microcavity corresponds to excitation of at most 3.2% of the DCM molecules—less than 1 nm worth of DCM if it were a neat film, ceteris paribus. This suggests laser action should be achievable with gain layer thicknesses of less than 20 nm and could lead to increased sensitivity of laser based chemo sensors.