Optical spectroscopy of advanced materials for energy harvesting

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Organic-inorganic perovskites (as prototype $CH_3NH_3PbX_3$, $X=I^-,Cl^-,Br^-$) have attracted great interest in the last decade especially for photovoltaic applications [1] because of some peculiar properties. In particular their high absorption coefficient in the visible spectrum ($\alpha \approx 10^5 cm^{-1}$ [2]) and the large carriers diffusion length, exceeding 100nm [3,4] in this kind of materials, make them very attracting for the development of a new generation of solar cells. Presently, the efficiency of perovskites-based solar cells has reached values of 20% to be compared to an estimated limit of ≈30%. These materials show also high photoluminescence emission (PL), making them ideal candidates for LEDs and lasers in the entire visible range (from ultraviolet to near infrared [5]). Recently amplified spontaneous emission (ASE) with low power threshold ($P_{th} \approx \mu J/cm^2$) has been observed in perovskites, both at room than cryogenic temperature [5,6,7]. Perovskites can be deposited as ordered wires/plates with typical size of microns or layers of disordered nanocrystallites can be realized.

Nevertheless, photoluminescence emission and exciton dynamics in perovskites it is not yet fully understood. Photoluminescence depends on a lot of parameters (temperature, crystalline phase, ordered/disordered deposition, excitation density [8,9,10]) and it is not clear if it arises from recombination of free electron-hole pairs or excitons. Moreover, perovskites show an anomalous band gap behavior with temperature, quite uncommon in semiconductors. Different properties of the ASE are reported and not understood in ordered and disordered deposition and the origin of ASE is debated in literature, especially in disordered systems.

My project research will focus on the understanding of PL emission in methylammonium lead halide perovskites through time integrated and time resolved spectroscopy measurements. In particular I'll study:

- charge recombination dynamics in perovskites solar cells with different electron and hole transport materials.
- the features of ASE (polarization and localization of emission, recombination dynamics, power threshold), both in nanostructured perovskites sample (microplates and nanowire) and in disordered perovskites thin films. Preliminary results provide clear evidence of a narrowing of the emission and a dramatic fastening of the recombination dynamics when lasing occurs. Spatial maps of emission will give us information on localization and the relationship between lasing and polarization is under investigation both in nanostructured and in disordered perovskites.

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