Rare earth doped oxides for solar energy application

Candidato: Alfredo Brugioni (alfredo.brugioni@stud.unifi.it)

Relatore: Dott.ssa Elisa Sani **(**elisa.sani@ino.it)

Correlatore: Prof. Francesco Saverio Pavone (francesco.pavone@unifi.it)

Up-conversion (UC) and down-conversion (DC) are mechanisms of light-matter interaction where a given wavelength is absorbed by an optically active material, which emits a shorter or longer wavelength luminescence (in case of UC and DC, respectively). UC and DC have been widely studied in the literature on a large variety of materials and for many applications, since the very beginning of solid-state laser era. Optical spectroscopy techniques are the election tool for assessing the presence of these mechanisms, as well as for characterizing their occurrence paths and application potential.

One of the potential field of application of UC and DC is solar energy. Looking at silicon solar cell technology, which is the leading photovoltaic technology, the major loss mechanisms of a conventional solar cell are optical spectral losses, due to the spectral mismatch between solar spectrum and silicon solar cell responsivity. The net result is that only about 48% of the sunlight irradiance is exploited to generate electrons. One of the potential approach in order to reduce the spectral mismatch is that of adapting the solar spectrum to better match the solar cell through UC and DC. In the case of UC, two lower energy photons are added-up to give one higher energy photon, thus converting sub-band-gap photons, otherwise lost, intro supra-band-gap photons, available to be absorbed. In the case of DC, the opposite process arises, whereby one high energy photon is split into two lower energy photons, having the chance of reducing the energy loss due to thermalization of electron-hole pairs.

In this work of thesis we have investigated the steady-state optical properties of some rare earth-doped oxide solids, in order to assess their potential as down-converters and up-converters materials, with specific interest on their application in the photovoltaics field.

A part of the work has been devoted to the optical investigation of the DC properties of some Yb-doped scheelite-like single crystals, materials from solid-state laser world and recently proposed as down-converters. Under UV pump, the disordered nature of crystal hosts give rise to a broad and strong emission band around 1 μm, demonstrating the efficient energy transfer between the host band states and the dopant Yb^{3+} ions. The comparison between the concentration-dependent Yb emission intensity under host pumping and under direct Yb pumping has allowed to prove the presence of DC. The possibility of producing these materials in form of ceramics and glass-ceramics is a large technological advantage, clearly encouraging for photovoltaic applications.

The other part of the work has concerned about the interesting luminescent properties of some industrial Er-doped zirconia ceramics. The spectroscopic investigation under infrared pump at around 1535 nm and 969 nm has shown the presence of UC mechanisms within Er^{3+} ions. The very low abundance of doping ions, conceivable on the basis of the industrial nature of the material, which was developed and optimized for non-scientific purposes at all, together with the excellent properties of the host and its ceramic nature, give to these samples extremely interesting perspectives.