

# Large Hollow-Core Fiber Random Dye Laser

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Random lasers (RL) have several interesting features that cannot be achieved with common bulk or fiber lasers such as simultaneous emission of several different wavelengths at the same time [1] and emission at new extremely low gain lines [2]. They also permit miniaturization and very low cost. To make the random emission useful, some sort of guiding mechanism that collects the stimulated emission is desirable [3]. In this work we propose the use of a hollow-core photonic crystal fiber (HC-PCF) based on a large-pitch Kagomé lattice to achieve a quasi-one-dimensional random laser (1D-RL) emission. The effective guiding property is demonstrated by a lower threshold of the high-gain scattering media RL inside the HC-PCF when compared with bulk RL emission inside a fluorescence cell.

The HC-PCF used in the experiment has the following structural dimensions [4]: core size = 68.3  $\mu\text{m}$ , cladding pitch = 11.8  $\mu\text{m}$ , strut width = 0.51  $\mu\text{m}$  and air-filling fraction = 0.91. The active fiber length, optically and transversally excited by the pump laser, was of approximately 5.0 mm. The scattering gain media (a mixture of 250 nm sized rutile particles in a solution of rhodamine 6G and ethylene glycol) was inserted using a syringe to press the ultrasonically dispersed liquid into the core, leaving the cladding filled with air. The dye and scattering concentrations were varied in the range of  $10^{-4} \text{ M} \leq \rho_{\text{dye}} \leq 10^{-3} \text{ M}$  and  $10^8 \text{ cm}^{-3} \leq \rho_{\text{scatt}} \leq 10^9 \text{ cm}^{-3}$  for comparative purposes [3]. For  $\rho_{\text{scatt}} = 10^8 \text{ cm}^{-3}$ , the average distance between scatterers is 21  $\mu\text{m}$  [3], occurring scattering events for photons that radically cross the PCF core, but, even so, total internal reflection is a fundamental mechanism that transversely confines light, as the core index is basically that of ethylene glycol (1.43) and the cladding air-filling fraction leads to a cladding effective index that is close to that of air.

The fiber was transversally pumped using the second harmonic of a Q-switched Nd:YAG laser (532 nm, 4 ns, 10 Hz). The beam was focused on the final portion of the PCF using a 6.4 mm focal length cylindrical lens. The incident laser intensity was varied from 1  $\mu\text{J}$  to 4000  $\mu\text{J}$  using a mechanical attenuator. The light emitted along the PCF axis was collected by a 0.22 N.A optical fiber and then sent to a spectrometer of 3.5 nm resolution.

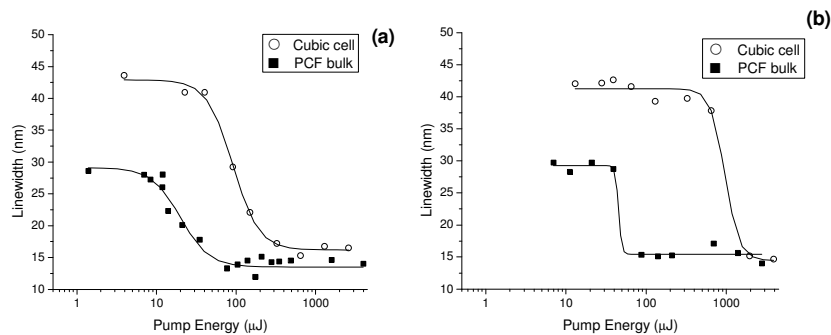


Fig. 1: Linewidth versus pump energy for a  $10^{-4} \text{ M}$  Rh 6G solution with (a) and without (b)  $10^8 \text{ cm}^{-3}$  rutile particles. Circles represent the emission by the fluorescent cell (cross-section 10mm x10mm) and squares represent emission of the large core PCF bulk. The solid lines are guides to the eyes.

The obtained results show that the threshold pump energy for the laser action of the RL can be reduced by at least a factor 3 when using a PCF (Fig.1a). During the experiment, a strong and well collimated yellow emission, around 570 nm, was observed. We can also observe a strong reduction in linewidth for the pure dye solution (Fig.1b); suggesting ASE (amplified spontaneous emission). In summary, the use of the Kagomé fiber permits a quasi 1D-RL that could be used in diverse applications.

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