Building a Fiber-based Quantum Dot Laser

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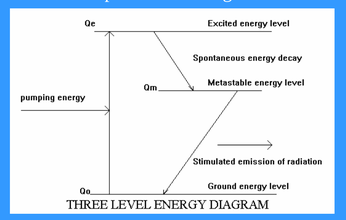
Introduction I: Laser Basics and the Advantages of Q-Dot Lasers

Laser Basics:

- A laser is an amplifier that functions at or near optical frequencies whose defining characteristics are directionality and coherence.
- Stimulated emission can only occur when a population inversion is achieved. In this state, the metastable energy level in the diagram below has a larger population than the ground state. This is induced through pumping the active medium with radiation of a shorter wavelength than that emitted by the laser.
- A resonant optical cavity is placed around the active material to "pick out" the amplified wavelength of interest.



THREE LEVEL ENERGY DIAGRAM

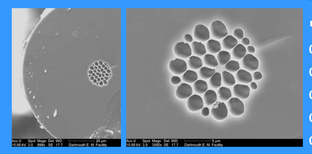
http://www.fas.org/man/dod-101/navy/docs/laser/fundamentals.htm

Q-Dot laser advantages:

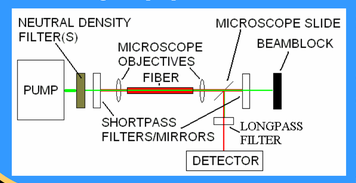
- More robust than dyes
- More tunable than materials such as ruby
- Less bulky than other robust, tunable systems (Ti:Sapphire, etc.)

Introduction II: Holey Fibers and Our Laser Design

Holey Fibers:



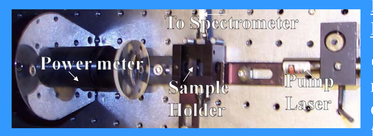
- The large refractive index difference between high index core and low index holey cladding ensures the confinement of beam to the core.
- If the holes in the cladding are coated with a thin film of active medium (Q-Dots or Rhodamine 6G laser dye in our case) the refractive index difference and thus confinement are to a large extent maintained while allowing the active medium to fluoresce into the core. The interaction strength can then be chosen independently of the fiber waveguide properties.



Our Design:

- The holey fiber contains either Rhodamine 6G dye or Q-Dot active media
- The dye was used first to verify experimental techniques

Experimental I: R6G Fluorescence Measurements and Fiber Loading



R6G Fluorescence:

- Quantitative measurements of R6G dye fluorescence
- Dye/host solutions were placed in a disposable cuvette and excited using the pump laser (output wavelength 532 nm). The power meter enabled monitoring of the pump laser output.

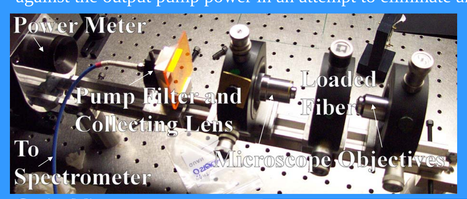
Fiber Loading:

- The fiber was threaded through the septum cap with a ½ mL insulin syringe. The cap was screwed onto a 1.5mL vial containing the solution to load. The 10 mL syringe was then used to over-pressurize the vial.

Experimental II: Amplification Tests and Cavity Mirrors

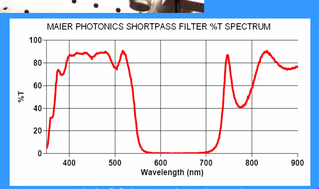
Amplification Tests:

The setup (below) was pumped from the right with an Ar^+ laser. The intensity of the beam was modulated through the use of neutral density filters. The peak fluorescence intensity was measured and plotted against the output pump power in an attempt to eliminate any variables involving changes in coupling efficiency.



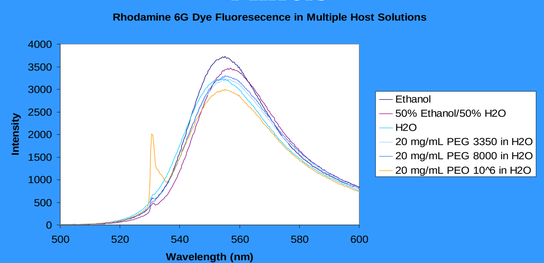
Cavity Mirrors:

- The manufacturer's specifications (right) involving transmittance of pump radiation and reflectance of fluorescence were confirmed. An aluminum mirror was used as a standard.



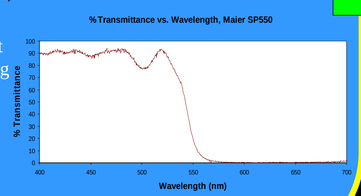
Courtesy Chris Maier, Maier Photonics

Results I: R6G Fluorescence and Cavity Mirrors



R6G Fluorescence:

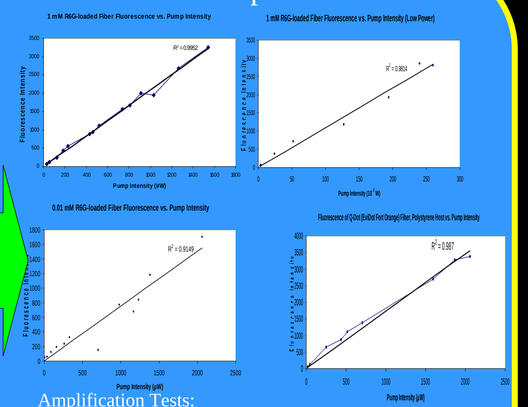
- Fluorescence strength is not seriously affected by changing the solvent or by using PEG/PEO hosts.



Cavity Mirrors

- The mirrors matched the specifications quoted by the manufacturer.

Results II: Amplification Tests



Amplification Tests:

- The measurement method yielded reproducible results, however all fluorescence data involving both R6G dye and Q-Dots were linear with respect to pump intensity (no was amplification observed).

Future Work

- Experiment with thin film host concentrations/refine loading techniques in order to better maintain beam confinement in the core
- Pump loaded fibers at higher power levels to find amplification threshold
- Once amplification has been observed, construct an optical cavity and try to observe lasing

Acknowledgments

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