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Optimization and Modeling of Multimode Raman Fiber Laser:

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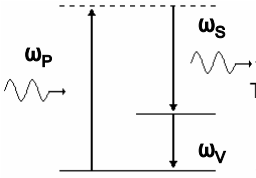
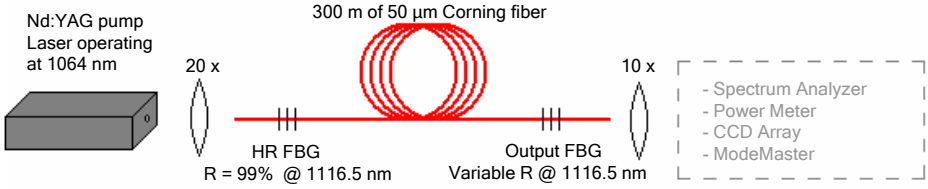
Raman Fiber Lasers

First discovered in the 1970s, the Raman Fiber Laser (RFL) may be the laser of the future. Fiber lasers possess several advantages over conventional lasers such as frequency selection and high beam quality. These differences arise from a unique method of lasing. Rather than electron transitions, RFLs make use of a process known as Raman scattering.



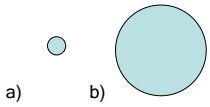
A pump photon enters a material and collides with one of the molecules, raising it to a higher vibrational state. The excess energy is then radiated as a photon of lower frequency, called a Stokes photon. This is normally a rather weak process resulting in very little Stokes radiation. However, when sufficient intensities of both pump and Stokes beams are present, stimulated Raman scattering (SRS) occurs and the Stokes beam is generated at a much faster rate. In order to induce this effect, we have created a fiber laser cavity terminated by fiber bragg grating (FBG) reflectors:



Why Multimode?

RFLs have traditionally been constructed using single mode fiber. The small diameter (< 10 µm) core restricts the light to the fundamental mode of the fiber, thereby ensuring good beam quality.

Our group has switched to multimode fiber. The larger core allows more power to be coupled into the fiber, thus allowing higher power lasers. Although it seems that beam quality should suffer, both theory and recent experiments have demonstrated a single mode output.



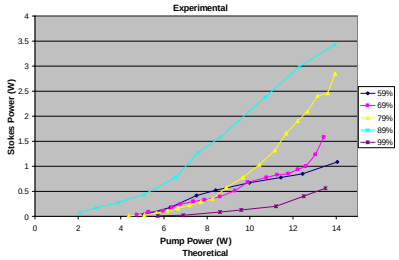
Comparative Core Sizes
a) Single mode
b) Multimode

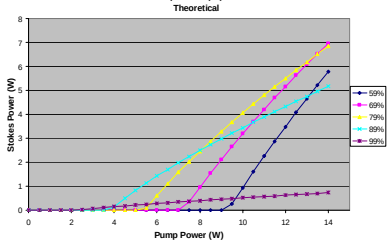
Output Stokes Power: Experiment vs. Theory

The graphs to the right show the effect of output reflectivity on power. The theoretical predictions seem intuitively correct. Higher reflectivities correspond with lower lasing thresholds. This makes sense. Lower reflectivities have larger slopes. This too makes sense, because as reflectivity decreases, more light is allowed to escape the cavity.

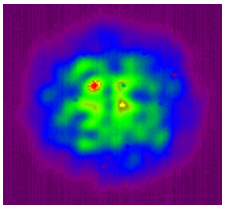
Unfortunately, the experimental data does not agree very well with the theoretical. Though there is clearly a distinct possibility that the model is somehow flawed, there are a few factors which could explain the differences:

- Looking at the experimental data, one can see that near threshold (< 1 W) the power rises slowly. Soon after, however, it takes off into the more linear shape predicted by the model. If we are failing to account for some low power process such as spontaneous Raman scattering, then the model might be valid at higher powers, and this would go a long way to explaining the discrepancies between model and experiment.
- The fault may not lie with the theory, however. We found that the power is very alignment sensitive. Coupling the pump laser into a 50 micron core is not easy and minute changes in fiber alignment can easily cut the power in half.
- Another problem which was recently discovered is that the FBGs are not operating at their labeled reflectance. This will obviously throw off any comparisons being made.

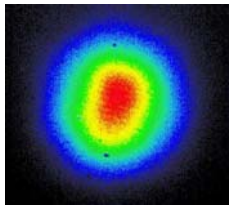




Beam Cleanup



Pump residue



Stokes beam

It is obvious looking at the intensity profiles that the Stokes beam, while originating from the multimode pump, has been 'cleaned up' and is now closer to single mode.

A more quantitative approach involves measuring the M^2 of each beam. This parameter describes how close a beam comes to a diffraction limited gaussian profile, with 1 being perfect. Using different output gratings, we have come up with the following results:

Output FBG Reflectivity	99%	89%	79%	69%
M-squared	2.4	3.1	2.1	1.8

These results suggest that perhaps quality is reflectivity dependent. More work will be necessary to verify this.