220b

1:15 pm

CThL2 Single-longitudinal-mode all-fiber ring laser

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The fiber laser is a potential laser source for fiber systems. To apply the fiber laser to optical coherent communications, especially for homodyne detection, it is necessary to narrow the laser linewidth. Several methods for narrowing output linewidth from a fiber laser were reported, such as using a fiber grating in laser cavity[1] or the Fox-Smith resonator.[2] In the cases the fiber laser has a large cavity loss and the manufacture technique is complicated.

Previously, we reported the all-fiber ring lasers with very low threshold.[3,4] In this paper, a novel single longitudinal mode all-fiber ring laser with compound fiber ring resonator is proposed. There are no reflective mirrors or grating in the fiber ring laser so that the cavity loss is low and the laser structure is simple.

The all-fiber ring laser has a compound resonator, as shown in Fig. 1, which is formed by two subrings connected by the tunable directional coupler DC 2. The subrings have the cavity lengths of L_1 and L_2, respectively. When there is no coupling between two subrings, the cavity resonance frequencies of each subrings are v_1 and v_2 which satisfied

$$v_1 = q_1 \frac{c}{nL_1}$$

$$v_2 = q_2 \frac{c}{nL_2}$$

where c is the light velocity in vacuum, n is the refractive index of the fiber core, q_1 and q_2 are integers. The resonance frequencies in each subring are a series of longitudinal modes, and the longitudinal mode frequency spacing is inversely proportional to the subring lengths L_1 and L_2. When the subrings are coupled to each other, they consist of a compound resonator. Only the frequencies that satisfied both of the subrings resonant conditions can be oscillated in this compound resonator (Fig. 2). Theoretical analysis shows that the longitudinal mode frequency spacing is

$$\Delta v = \frac{c}{n|L_1 - L_2|}.$$

The tunable directional couplers can be adjusted along the fiber axes, which can change the subring's cavity length. When the cavity length difference of the subrings $|L_1 - L_2|$ is small, the longitudinal mode frequency separation of the compound resonator will be large enough.

The fluorescent spectrum width of the ND^{3+} or Er^{3+} ions are dozens of nanometers. It is difficult to let the longitudinal mode frequency spacing Δv be greater than the width of the fluorescent spectra. In fact, the directional coupler has a good wavelength selectivity and can narrow the laser linewidth.[4] Our experiment shows that a single longitudinal mode laser output can be obtained when the mode spacing Δv has a width of the order of nanometers.

An all-fiber ring laser (Fig. 1) was fabricated by using Nd^{3+}-doped single-mode fiber. The subrings length were ~1 m. Pumped by an Ar laser at wavelength of 514.5 nm, a single longitudinal mode output was obtained. Figure 3 shows the laser spectrum. The linewidth is less than 0.08 nm, which is the resolution limit of the spectrum analyzer. Using a Fabry-Perot scanning interferometer with free-spectrum range of 4 GHz to measure the laser linewidth, we show that the laser linewidth is less than 40 MHz (resolution limit of the interferometer). This single longitudinal mode fiber ring laser is an ideal device for fiber ring laser gyro.

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1:30 pm

CThL3 Infrared thulium-doped fluorozirconate fiber lasers

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We have investigated the performance of Tm^{3+}-doped fluorozirconate fiber lasers when pumped at approximately 790 nm with a Ti:sapphire laser. This was done to assess which transitions are suitable for diode-pumping in addition to the $^3F_4$-$^3H_4$ transition (Fig. 1) near 2.3 μm, as previously reported by Allen and Esterowitz.[1]

We have also reported a diode-pumped Tm^{3+} fiber laser operating at 1.97 μm ($^3H_4$-$^3H_6$ transition),[2] but found that the performance of this device was poor as a consequence of the low branching ratio (10%) from the $^3F_4$ level (to which ions are excited by 790 nm photons) to the $^3H_4$ upper laser level and the low values of output coupling used (<1%), resulting from the need to reach threshold in a fiber of 40 μm core diameter. Despite using an output coupler of approximately 10% transmission at nearly 1.9 μm, when pumping with a Ti:sapphire laser, we were able to achieve only a slope efficiency of 3.2% with respect to incident pump power. By enforcing simultaneous oscillation on the 2.3 μm transition we were able to enhance the branching ratio to the $^3H_4$ level through stimulated emission to the $^3H_5$ level followed by multiphonon emission. With this technique we demonstrated a slope efficiency of 12.7% and extracted 70 mW at 1.92 μm.

Continuous-wave oscillation at 1.47 μm has also been observed when pumping at 790 nm. This transition has been found to be relatively inefficient since the lowest laser level, $^3H_4$, has a longer lifetime (6.4 ms) than the upper level, $^3F_4$ (1.1 ms).

More recent experiments have been carried out on a fiber of much smaller (7 μm) core diameter. With this fiber we demonstrated laser action at 803 nm when pumping at 777 nm. To date we have measured a slope efficiency of 15% with a maximum output power of 125 mW. Significant improvements on these results should be possible since this early sample of fiber has a scattering loss of a few dB/m. We believe this transition to be of great interest since both pump and emission wavelengths fall in the wavelength region covered by AlGaAs diode lasers. It may therefore be possible to extend the versatility of these lasers through techniques such as tunable operation, Q-switching, brightness enhancement, and amplification which may be provided by the Tm^{3+}-doped fluorozirconate fiber. Results dealing with these applications are presented.

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1:45 pm

CThL4 Crystal optical fiber laser with linearly polarized output

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Optical fiber communication, optical fiber sensors, and laser technology have rapidly developed, making a lot of scientists and engineers interested in fabricated function devices. The development of technology of laser diode (LD) pumped solid lasers makes it possible to develop LD pumped crystal optical fiber lasers (COFLs). Some of this kind of COFL pumped by LDs have been reported. Until now COFLs with linearly polarized output have not been reported but are urgently needed for many technological fields. So we have worked on this kind of COFL and have successfully developed LD pumped COFLs with linearly polarized output. First, crystal optical fibers of YAP series have been fabricated by a laser-heated pedestal growth method. The maximum length of the fibers is 15 cm. The diameters are from 50 to 500 μm. The fluctuation of the diameters is smaller than 1%/cm. LD pumped Nd:YAP COFLs with linearly polarized output at 1.0795 μm have been fabricated, and their cw output power is larger than 2 mW. The threshold is 35 mW. The slope efficiency is larger than 5%. The quality of the crystal fibers and the polishing of the end facets and the mirrors has an important influence on the output power. We will report the fabrication procedure of COFLs and the results of the experiments.

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2:00 pm Invited

CThL5 Upconversion fiber lasers

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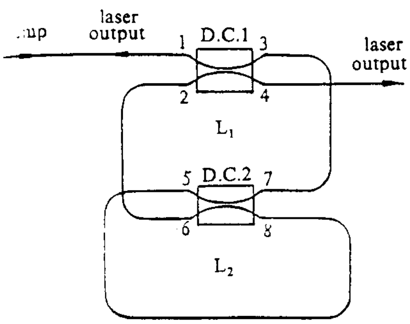
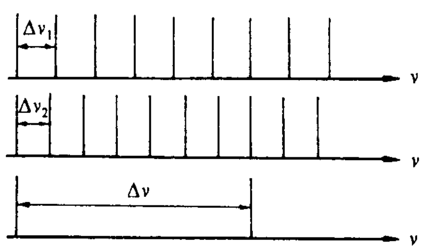
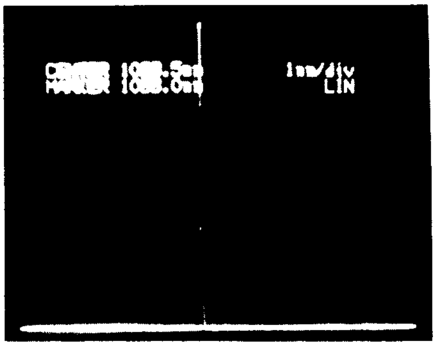
Upconversion presently receives much interest, mainly for the development of visible sources pumped in the near infrared. This has been realized in many crystals doped with rare-earth (RE) ions. Important objectives are obtaining room temperature cw operation and diode pumping. It is thought that optical fibers that have shown high performances in the laser domain[1] can bring major improvements in the upconversion process, owing to their unique properties of light confinement over long lengths.



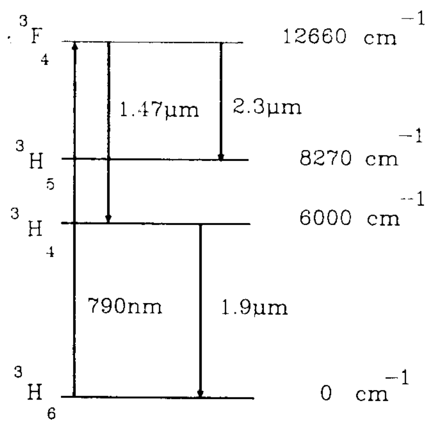
CThL2 Fig. 1. All-fiber ring laser with compound resonator



CThL2 Fig. 2. Frequency spacing of the compound resonator



CThL2 Fig. 3. Spectrum of the single longitudinal mode fibers



CThL3 Fig. 1. Partial energy level diagram for thulium-doped fluorozirconate fiber.