26PB1 Narrow-Band Alexandrite Laser for DIAL and other Lidar Systems

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DIAL system development for atmospheric temperature measurement has shown some progress during the past 10 years through intense efforts at NASA as well as in European research communities. The main remaining difficulty in the technological development consists of the narrow absorption linewidth of oxygen in the atmosphere and the lack of a single mode laser source easily tunable through this region. Tunable dye lasers used by other research groups suffer from substantially broad linewidth and spectral impurity of over tens of percent which presents a major difficulty for DIAL measurement. An alternate solid state tunable laser system, specifically alexandrite laser, has been under intense development for the past decade for DIAL applications due to the potential of high spectral purity of the output. In a conventional standing wave cavity configuration, however, the promise of the high spectral purity has not been readily realized so far due to the specific characteristics of the alexandrite crystal and associated spatial hole burning of the laser system. An independent effort for the development of a high spectral purity alexandrite ring laser system was initiated by SESI in 1991 for DIAL applications. As a result, recently a single mode high spectral purity alexandrite laser system has been developed and delivered to NASA/GSFC P/T Lidar Laboratory under an SBIR contract. This new ring laser employs an injection seeding technique to tune the laser and narrow the linewidth in order to achieve nearly 99 % spectral purity, single mode output in the near ir spectral range.

Solid state alexandrite lasers have supplanted dye lasers because of the potential improvement in spectral purity, efficiency, and operational lifetime. The technique of injection seeding a high power laser with a stable low power laser of bandwidth 0.005 cm^{-1} or better has been proved superior to the use of many intracavity etalons. Injection seeded lasers have lower intracavity losses because only a coarse line narrowing element is used, and the frequency stability is readily controlled by the seeder emission.

A standing wave pulsed alexandrite laser tuned by injection seeding with an AlGaAs laser diode has demonstrated high stability ($<0.005 cm^{-1}/hr$), with a narrow band output spectrum [Schwemmer et al., 1991]. The standing wave cavity, however, poses several difficulties in light of the single mode, high spectral purity operation and efficient seeding due partly to the spatial hole burning effect and partly to difficulties in injecting the seeder beam into the cavity. In order to overcome these problems and to operate the high power alexandrite laser in a single axial mode with a high spectral purity, a new ring laser system has been developed by SESI.

Figure 1 shows the ring laser system layout. The three mirror 105cm triangular resonator includes a 10cm x 5mm alexandrite rod, electro-optic Q-switch and 3 plate birefringent filter (BRF) for coarse line-narrowing to $1cm^{-1}$. Careful alignment of the BRF is required for smooth wavelength tuning of the output. A 30mW cw AlGaAs diode laser, temperature tuned to the desired wavelength in the 760-770nm range, is coupled to the resonator through three -30dB optical isolators and a series of coupling lenses used for approximate transverse mode matching [Lee et al.,1991]. The diode beam is easily aligned to the slave laser cavity by observing the interference pattern caused by several successive passes at a screen placed outside the cavity at the output coupler. The diode laser is frequency stabilized to the O_2 absorption feature which is used for on-line measurement. The diode current is dithered at 10 Hz in order to cause the diode frequency to sweep across the full width of the absorption feature. A non-resonant photoacoustic cell, filled with O_2, is used to generate a feedback signal, locking the laser to the absorption line. The alexandrite laser is timed to fire when the diode frequency approaches the absorption line peak, resulting in laser emission at the absorption peak frequency. Improved spectral emission characteristics of the alexandrite laser will be achieved by the addition of a control system for adjusting the optical path length of the alexandrite laser resonator. Information on the resonance of the injection seed laser is then used to adjust the perimeter length of the slave cavity by positioning a mirror mounted on a piezoelectric translator, matching the slave longitudinal mode frequency to the diode frequency.

Operational characteristics show single longitudinal mode output without cavity length control as indicated by the spectral output of an average of 20 - 70 mJ, 200 nsec pulses measured by a Fabry-Perot interferometer, shown in Figure 2. Figure 3 shows the spectrum from a Fizeau interferometer with a free spectral range of $0.1\ cm^{-1}$, depicting the single longitudinal laser output. Spectral purity measurements were performed by tuning the laser to an O_2 line and measuring the return from a retroreflecting target board placed on a tower at 850 m distance from the lidar test facility. These measurements have shown a spectral purity figure of >98.5% (see Figure 4.) It is anticipated that with cavity length control the laser will meet the design goal of better than 99% spectral purity with a frequency drift of $< \pm 0.005cm^{-1}$. An improved laser system including implementation of cavity length control will be an integral part of future lidar systems.

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G. K. Schwemmer, H. S. Lee, C. R. Prasad, "Narrowband alexandrite laser injection seeded with frequency dithered diode laser," *Earth and Atmospheric Remote Sensing*, R. J. Curran, J. A. Smith, K. Watson, eds., Proc. SPIE 1492, pp. 52-62, 1991.

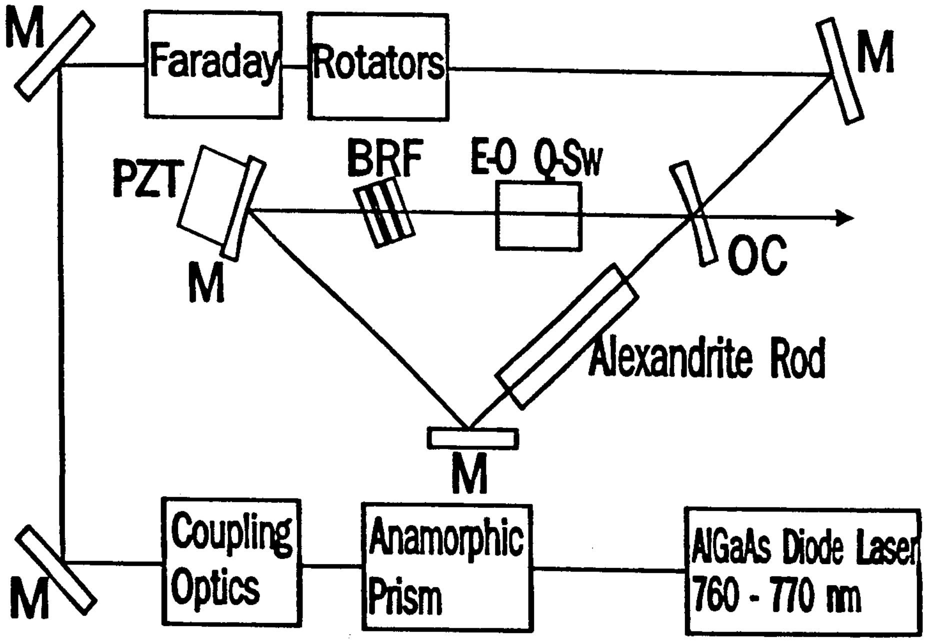

Figure 1. Alexandrite ring laser configuration with injection seed diode laser. Shows mirrors M, piezoelectric translator PZT, birefringent tuner BRT, electro-optic Q-switch E-O Q-Sw, and output coupler OC.

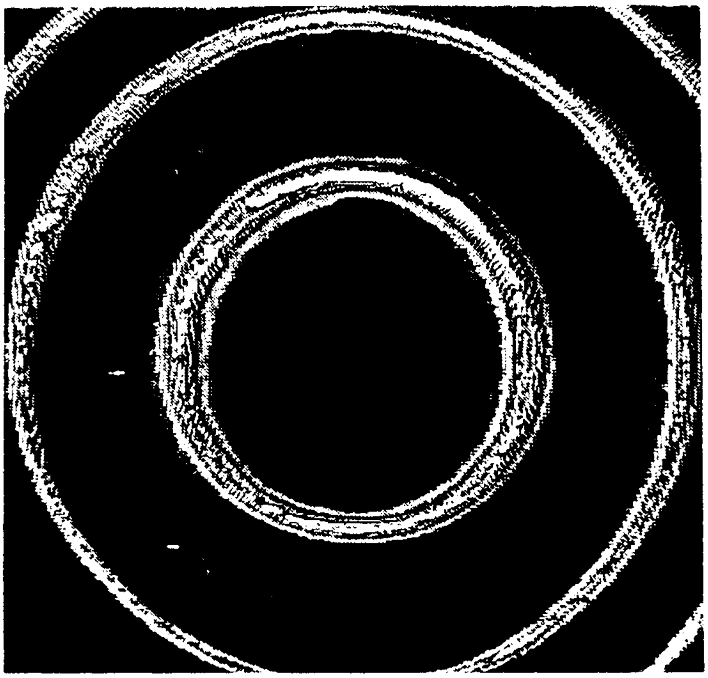

Figure 2. Fabry-Perot interferometer spectral analysis of single mode alexandrite laser emission, average of 20 pulses.

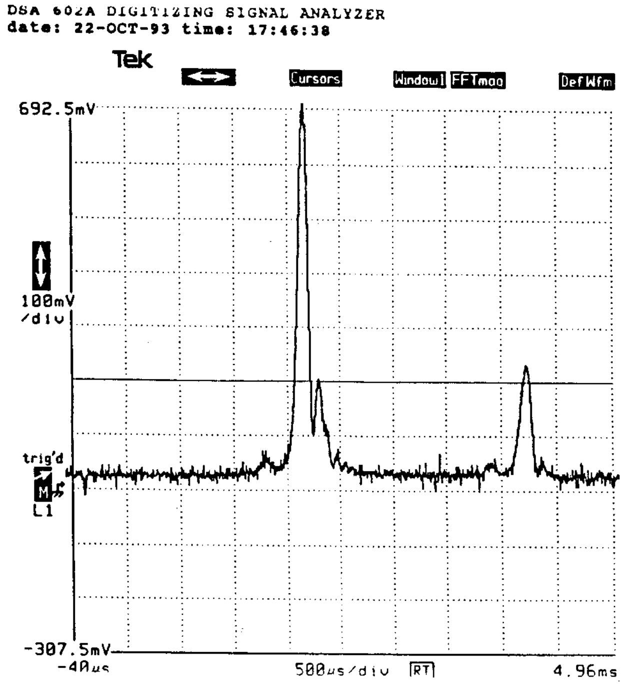

Figure 3. Laser wavemeter spectrum showing single mode, with weak second mode.

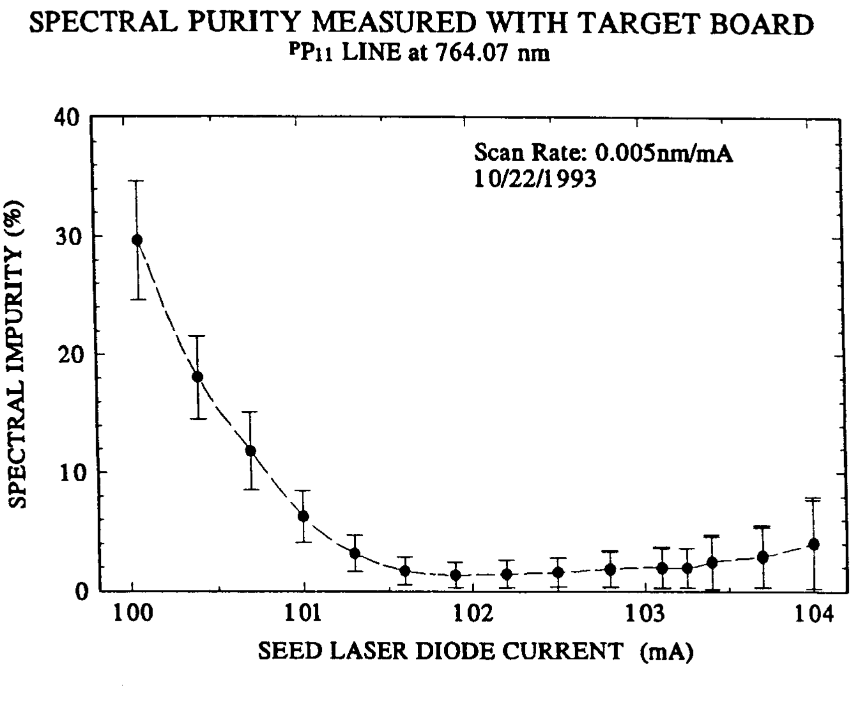

Figure 4. Average spectral impurity of seeded alexandrite laser tuned over ${}^{P}P_{11}$ O_2 line.