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# Resonance Lidar to Study Temperatures, Winds, and Metal Densities in the Upper Mesosphere and Lower Thermosphere

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Resonance Lidar to Study Temperatures, Winds, and Metal Densities in the Upper Mesosphere and Lower Thermosphere, *V. B. Wickwar, T. D. Wilkerson, D. Rees and S. C. Collins, Center for Atmospheric and Space Sciences, Utah State University*

Utah State University (USU) received a CEDAR infrastructure award to obtain an alexandrite ring laser from Light Age, Inc. (LAI) to make resonance-scatter lidar observations. Currently, we are obtaining temperatures between 30 and 90 km with Rayleigh-scatter observations. One of the goals with the alexandrite is to extend the temperature profiles upwards to 105 km and to do so with good time resolution. (This will also enable us to improve the accuracy of the Rayleigh temperatures between 70 and 90 km.) Because many effects originate low in the middle atmosphere and grow with altitude, the resulting continuous range of observations between 30 and 105 km is much more valuable for understanding the physics than small portions of the range. For instance, we will be better able to examine the interactions among gravity waves, tides, planetary waves, and winds that give rise to critical layers, wave saturation, and possibly to the recently discovered double mesopause. Other goals include making wind observations between 80 and 105 km and examining the distributions of several different species of metals that arise from meteoric deposition. A technological goal is to demonstrate that an alexandrite-based lidar provides a simple way to obtain resonance-scatter temperatures and winds.

This alexandrite laser is the culmination of a lengthy development by LAI for von Zahn's research group, first at Bonn, now at Kühlungsborn. Our group and the one at Arecibo have gained considerably from this development effort. The characteristics of this laser and its ring configuration are ideal for resonance-scatter observations. Alexandrite lasers are vibronic, or phonon-terminated, i.e., a close coupling exists between vibrational and electronic states in the crystal lattice that allows the laser to be tunable over an extended range of wavelengths—720 to 810 nm. This provides access to important resonance lines: the K resonance lines can be reached directly; the Ca and $Mg^+$ lines can be reached by a combination of tuning, Raman-shifting in $N_2$, and frequency doubling; the $Ca^+$, Al, Mg, and Fe lines can be reached by tuning and frequency doubling; and Na can be reached in two ways that are described below. With this laser, unidirectional ring lasing is established in a two-rod cavity, producing single longitudinal and transverse mode ($TEM_{oo}$) pulses having an energy output of 250 mJ with a pulse length of 100 ns and a repetition rate of approximately 25 Hz. These characteristics give rise to pulses with spectral widths of the order of 30 MHz. After Raman shifting and frequency doubling, we would still have pulses with spectral widths less than 100 MHz, which is important for obtaining good temperatures and velocities.

Controlling the gain of the alexandrite ring resonator is accomplished by seeding the cavity with narrow-band radiation from a semiconductor CW laser diode. These laser diodes have extremely narrow linewidths and are relatively easy to control in frequency (wavelength). With the ring resonator locked to the laser diode, the output of the alexandrite laser has the same frequency as the laser diode and a spectral width that is only slightly greater. Thus, the laser is tuned by picking the appropriate laser diode and tuning it by varying its temperature and the current across its semiconductor junction. Similarly, the laser is stabilized by stabilizing the laser diode. This is done by careful thermal control of the laser diode and by means of a feedback loop involving changing the current to the laser diode to maximize the light from the diode that passes through a Fabry-Perot etalon. Thus the laser diode is locked to the etalon, which provides ultimate frequency control both for tuning and for stability. It is in this etalon that our version of the alexandrite ring laser differs from the others. The etalon, provided by Hovemere, Ltd., is hermetically sealed and temperature controlled. The plate separation is controlled by piezo-electric crystals that are capacitance stabilized. The separation can be held constant to stay at one frequency or stepped to scan in frequency. This type of capacitance-stabilized etalon (CSE) has been well tested in FPIs used for airglow wind and temperature observations and in very precise wavemeters. In addition to high precision, the CSE provides great flexibility when changing from one resonance line to another.

The CSE was integrated into the laser at LAI in November 1995. Simultaneously, a Hovemere, Ltd., high-resolution laser wavemeter (LWM), for assessing the spectral quality of the beams from the laser diode and the ring laser was deployed at LAI. They were subsequently transported to USU, and the alexandrite ring laser was installed at the Atmospheric Lidar Observatory (ALO) in February 1996. Since then, the development effort has been concentrated on two areas: characterizing and optimizing the frequency stability of the laser diode and laser and testing procedures for generating emission at the frequencies of the Na D2 lines (at 589 nm). This emission can be obtained by frequency doubling the first Stokes emission when laser output at 791 nm is Raman shifted in $H_2$. It can also be obtained from the first anti-Stokes emission when laser output at 780 nm is Raman shifted in $H_2$. These two procedures are currently being compared. The first method has been used previously. Initial tests of the second method indicate that it may be nearly as good, while being simpler to implement. (It is also easier to locate good 780-nm laser diodes than 791-nm laser diodes.) This laboratory work relies heavily on the LWM, which will later be used in real time to analyze each emitted laser pulse to ensure that it has the correct wavelength, spectral width, and energy. When the next round of operations funding, we look forward to turning the beam skyward and beginning Na temperature observations. When the new steerable telescope is finished shortly thereafter, we also look forward to starting wind observations.