Tunable Solid State Lasers for Remote Sensing

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A Solid State Tunable Laser for Resonance Measurements of Atmospheric Sodium

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The initial concept of an instrument to measure the wave dynamics in the upper mesosphere using a solid state laser to excite the resonance fluorescence line of sodium is discussed. The technique would make use of two Nd:YAG lasers to produce the sodium resonance line. The concept has been proposed for use in a space shuttle experiment.

INTRODUCTION

The most frequently used solid state laser is Nd:YAG which normally lases at 1064 nm, but another available transition for the same material is at 1319 nm. By mixing these two wavelengths in a nonlinear crystal, it is possible to generate a wavelength very near the sodium resonance lkne. In order to exactly tune the output to the sodium reaonance line, the wavelength of the 1064 nm laser can be tuned using an intracavity etalon. The feasibility of tuning the Nd:YAG laser to the wavelength required has been demonstrated in the laboratory (Marling, 1978). Even though no one has demonstrated the use of two Nd:YAG lasers to generate the sodium resonance line, all of the technical details needed to build such an instrument have been demonstrated. The idea of the sum frequency generation with Nd:YAG lasers, which makes this experiment possible, was first put forth by Aram Mooradian (private communication, 1983). The particular interest in generation of the sodium resonance line is to study the atmospheric waves and structure parameters using the meteoric sodium layer between 80 and 105 km as a tracer. A simple solid state laser for generation of the sodium resonance line could provide a major step toward a simple shuttle instrument for measurement of the horizontal scales of atmospheric waves.

LIDAR TRANSMITTER

In the previous developments of LIDAR instruments to measure Na, the laser transmitter has been a liquid dye (i.e. Rhodamin 6G), that is optically excited and tuned very precisely to the required wavelength. Dye lasers have the disadvantages of large size, system complexity, and a lack of ruggedized performance for the flight environment. The liquid dye and its fluid handling and cooling components are especially troublesome. In this effort, a fundamentally new and improved method is proposed for obtaining the required Na line radiation at 588.9 nm based on all solid state components. The primary laser source will be Nd:YAG lasers which have been commercially developed into compact rugged instruments suitable for being directly used in this flight application. Several companies have rugged instruments for 28 volt dc operation as off-the-shelf hardware. The method involves mixing the 1064 nm radiation with that from a second Nd:YAG operating at 1319 nm in a nonlinear infrared crystal to directly produce 589 nm radiation by sum frequency generation. Though not used as frequently, the Nd:YAG laser can be operated at 1319 nm by inhibiting the normal lasing at 1064 nm. In normal cw operation the output at 1319 nm is about 30% of the output at 1064 nm (Marling, 1978). It will be necessary to shift one of the wavelengths slightly to achieve the Na resonance. This method is inherently quite simple and should provide an effective all solid state source. The process of sum frequency generation has been developed analytically by Armstrong et.al.,(1962). The process is analogous to a second harmonic generation except that two different wavelength beams of comparable intensity are input to the crystal. By proper choice of crystal material, length, and angle-of-incidence, efficient mixing under Type I phase matching can result. The two Nd:YAG beams at 1064.1 nm and 1318.8 nm would result in an output of 588.93 nm which is 0.06 nm from the required wavelength for the sodium measurement. The work of Marling (1978) clearly demonstrates that the 1064 nm line can be tuned over more than the required range to produce the sodium wavelength required at 588.99 nm. Figure 1 shows the schematic diagram for the transmitter.

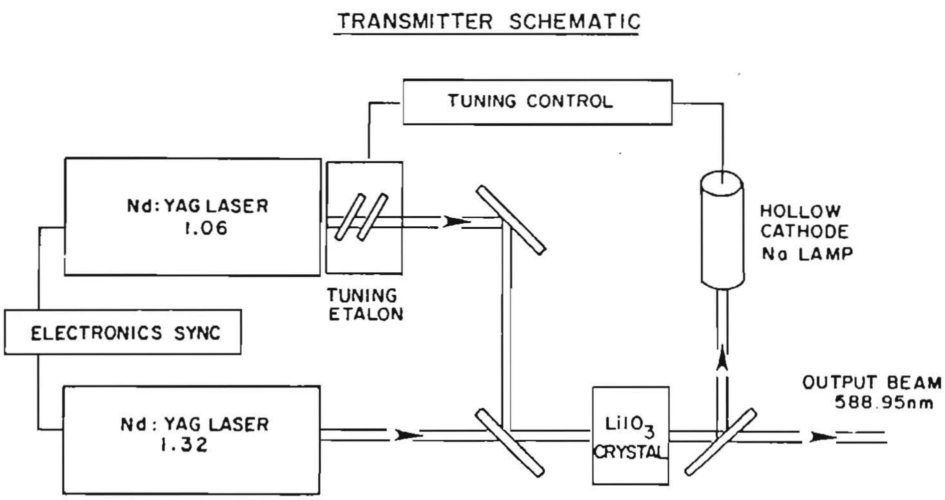

FIG. 1---Schematic diagram of the laser transmitter

CONCEPT FOR SHUTTLE EXPERIMENT

Plans have been developed to make use of a transmitter like that described in the previous section to measure the sodium layer from the space shuttle platform. The laser transmitter will require some effort to demonstrate the measurement from the ground, initially. The two lasers must be triggered together, the 1318 nm laser cavity must be spoiled for the 1064 nm wavelength, the etalon tuned cavity in the 1064 nm laser must be tested and the nonlinear crystal prepared. None of the tasks are expected to cause any major difficulties. In Figs. 2 through 5, the conceptual representation of the shuttle experiment is presented. The plan is to make use of the GAS (Get-

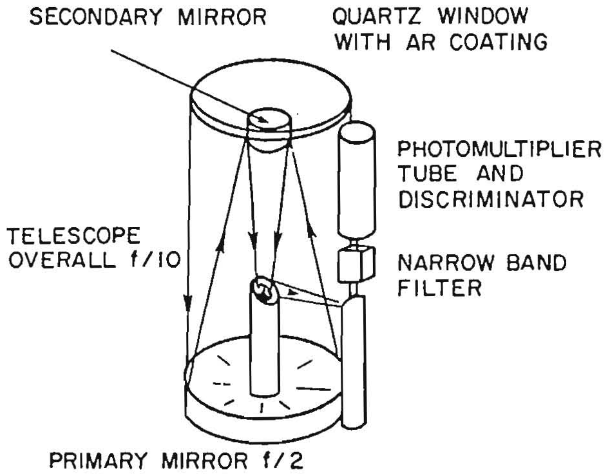

FIG. 2--Diagram of receiver configuration

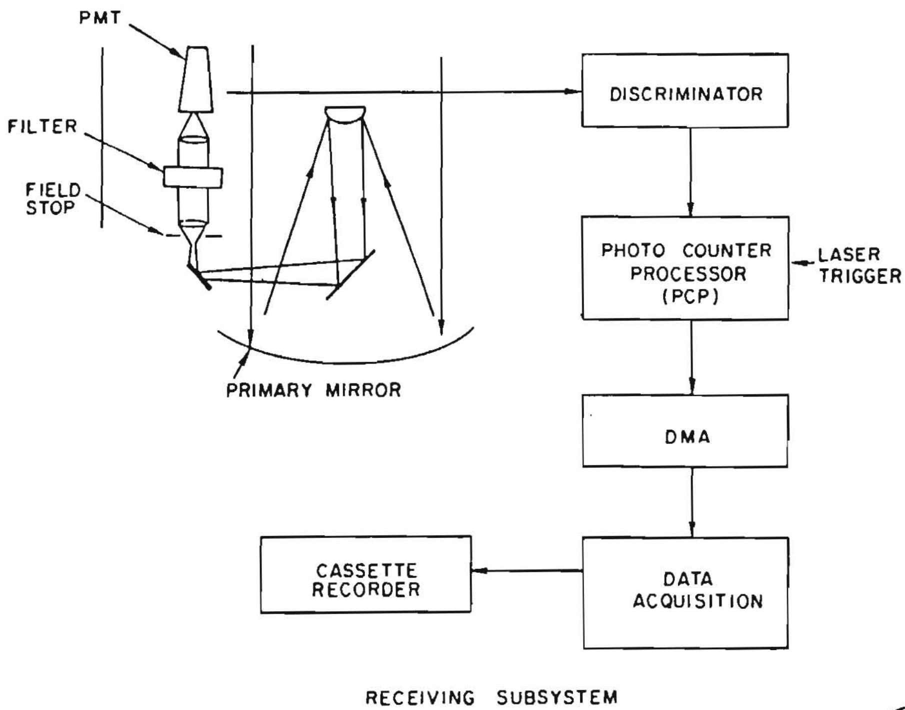

FIG.3--Components of the receiving sub-system

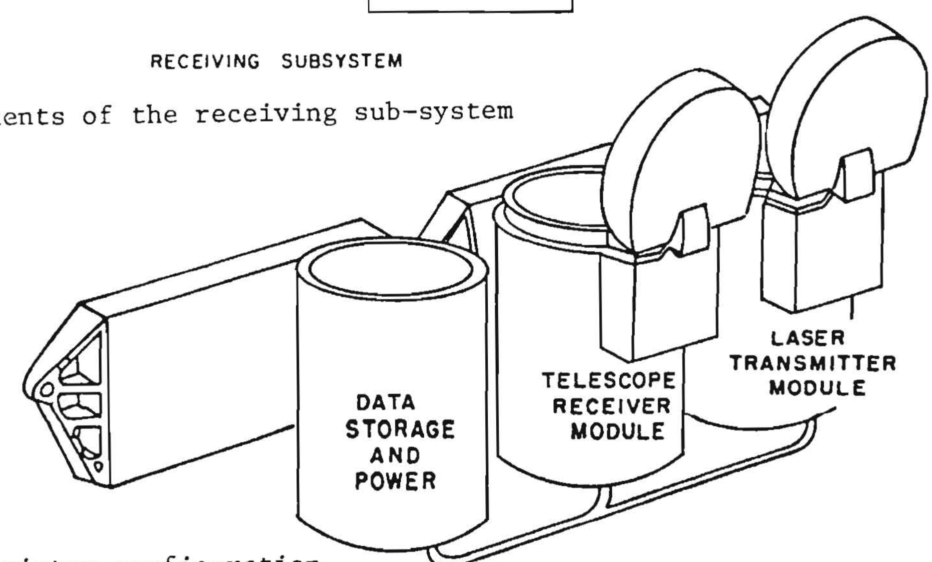

FIG.4--GAS canister configuration

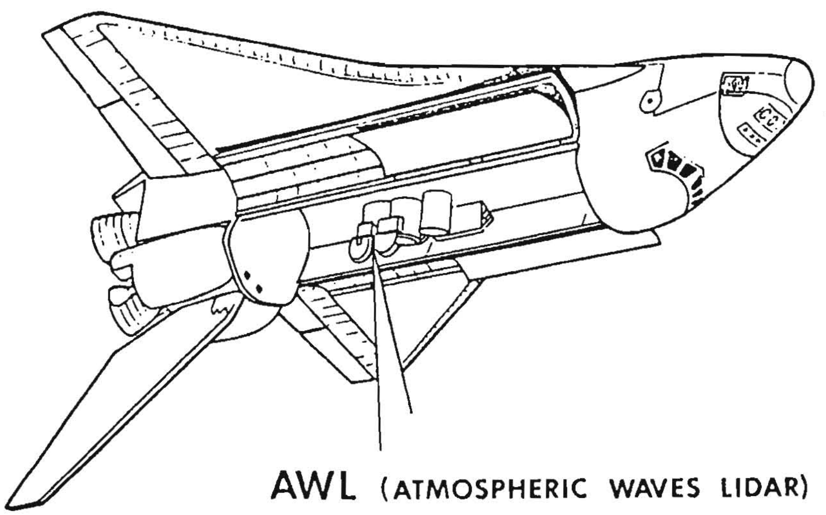

FIG. 5--Shuttle experiment conceptual drawing

Away-Special) canisters of the shuttle program to make early measurements of the horizontal scales of the waves in the sodium layer and the global distribution of the sodium deposition. Table I shows the parameters for the LIDAR system and Table II shows the expected signal levels.

TABLE 1 - Lidar System Parameters

Primary Mirror	38 cm diameter, f/2
Effective Receiver Area	$0.122\ m^2$
Field-of-View	10 mrad
Bandwidth	2 nm FWHM
Laser Energy	50-100 mj
Receiver Efficiency	0.06
Range Resolution	150 m
Integration Time	4 sec (20 shots)
Horizontal Resolution	32 km
Altitude Range	250-400 km
Effective Backscatter Cross-section	$2 \times 10^{-16}\ m^2$ (10 pm linewidth) $8 \times 10^{-16}\ m^2$ (1 pm linewidth)

Table 2 - Expected Signal Levels

Z (km)	E_T(mj)	Linewidth (pm)	N^*_{tot}
250	50	10	14-56
250	100	10	28-112
250	50	1	56-225
250	100	1	112-450
400	50	10	3.7-15
400	100	10	7.5-30
400	50	1	15-60
400	100	1	30-120

*Column Abundance $= 2$ to $8 \times 10^{13}\ m^{-2}$

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