GENERATION OF 369.4 nm RADIATION BY EFFICIENT DOUBLING OF A DIODE LASER

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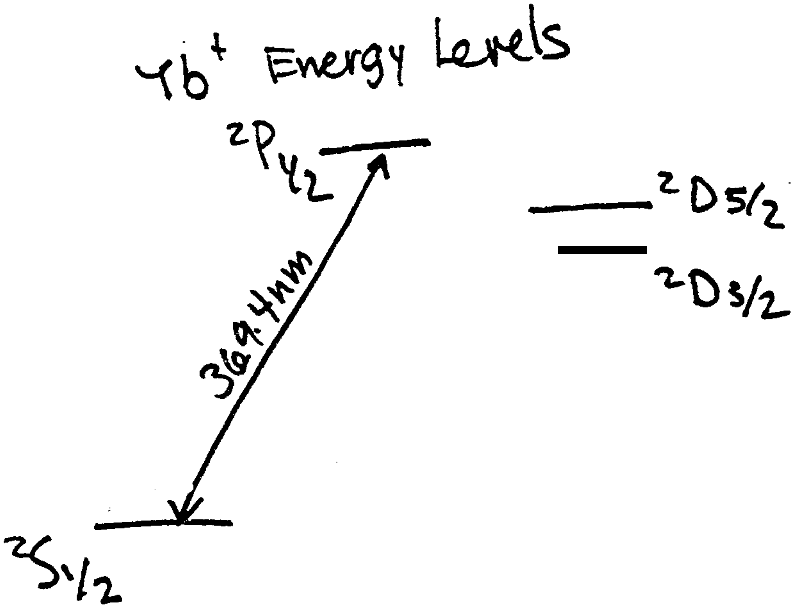
INTRODUCTION

The trapped ytterbium ion frequency standard under development at JPL is designed to supply ultra-stable reference signals to be used in spacecraft tests of general relativity, and other science experiments. This device requires at least 10 μW of continuous-wave (cw) laser radiation at 369.4 nm to optically pump the $^2S_{1/2} \Leftrightarrow {}^2P_{1/2}$ transition in Yb^+.



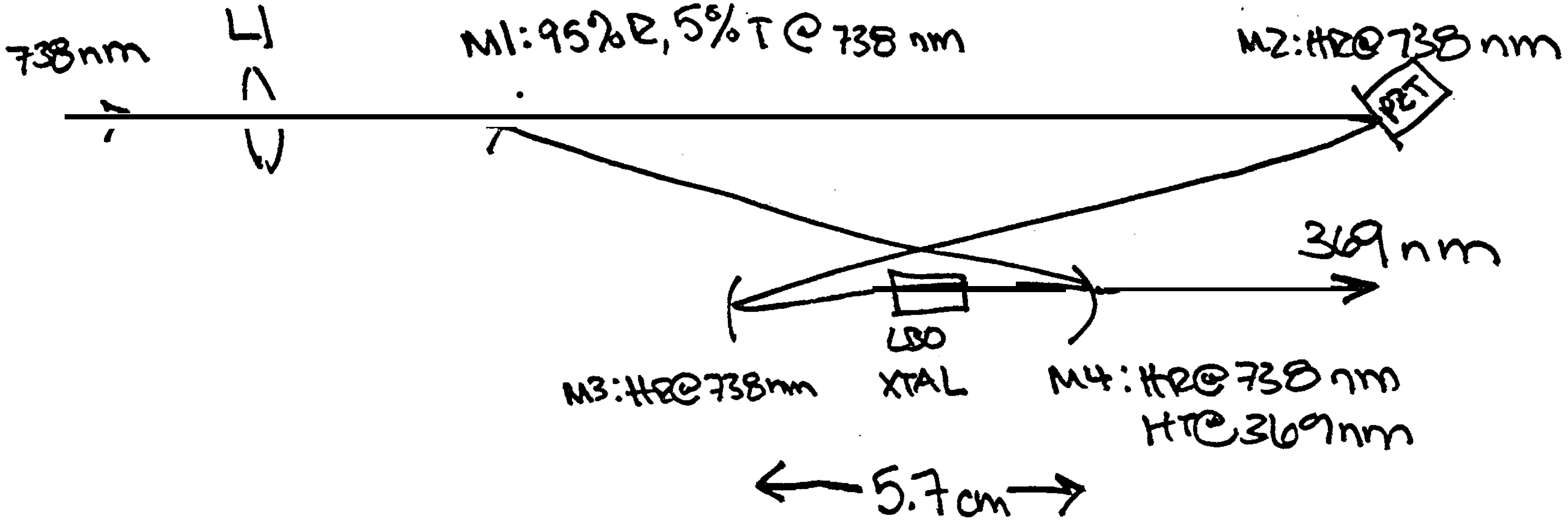
Only diode lasers meet the requirements of low power consumption and small size for use aboard spacecraft , but diode lasers are not currently available at this wavelength. It is therefore necessary to employ frequency-doubling methods to reach 369.4 nm with diode lasers. Here we present the characteristics of the resonant cavity doubling system we have designed, and preliminary uv conversion results.

We have obtained 738.8 nm AlGaAs quantum well ridge waveguide diode lasers from the Micro Devices Laboratory at JPL. These lasers employ a GRIN structure to confine the optical energy, and have typical output powers of 10 mW. Low doubling efficiencies at milliwatt input power in available nonlinear crystals requires us to employ a buildup cavity and beam focusing to achieve uv conversion from these diode lasers.

Some of the popular doubling crystals are not transparent at 369.4 nm. Of those that are, we selected lithium triborate (LBO) for its large acceptance angle. Tight beam focusing can then be employed to increase uv conversion efficiency. Our 3 **x3x** 10 mm LBO crystal is antireflection coated for the fundamental wavelength of 738.8 nm, and has optimum uv generation with a beam waist of 26 μ.

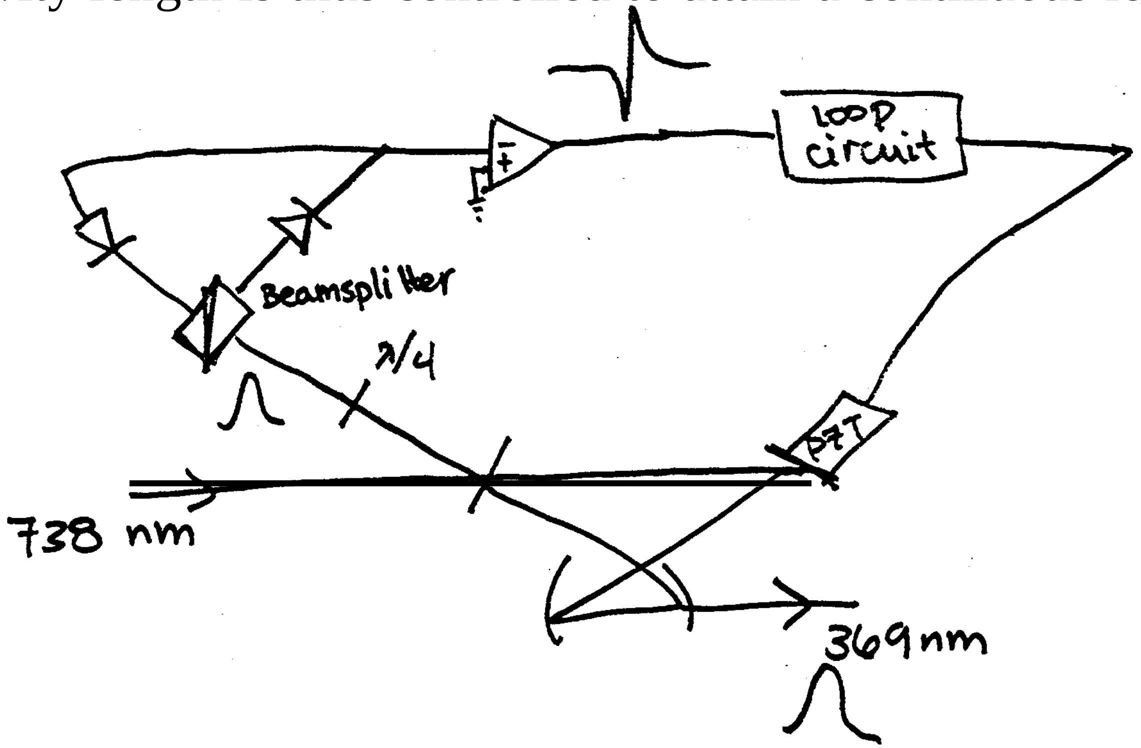
xtal	transparency range (nm)	angular acceptance
$KNbO_3$	400-4500	29 mrad·cm
KTP	350-4500	13 mrad·cm
BBO	190-3000	<1 mrad
LBO	160-2600	82 mrad.cm

We use a folded-ring optical resonance cavity to increase the power of the fundamental available to the LBO crystal.

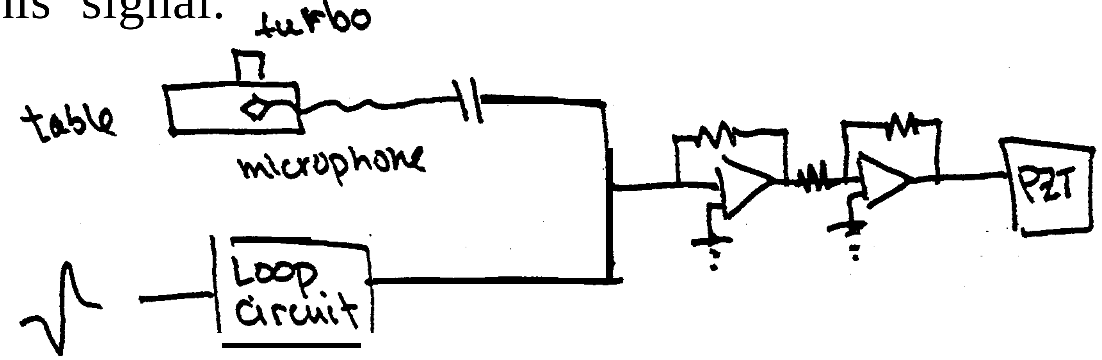


The curved mirrors M3 and M4 (R_{cc} = 5 cm) allow the desired beam focusing. We chose an input coupler (M1) with 95% reflectance since the calculated loss due the other three mirrors and the LBO crystal was ~5%. The small folding angle (~5°) reduces astigmatism and conforms to restrictions on spacecraft instrumentation size. Lens L1 (f = 160 mm) allows accurate mode matching to the TEM_{00} cavity mode.

We employ a polarization locking scheme to servo-lock the cavity to the laser wavelength. The beam consisting of the input light reflected by Ml and the built-up light transmitted through Ml is passed through a quarter-wave plate oriented at 450 and a polarizing beamsplitter cube. The two intensities are detected by photodiodes, and subtracted to give an error signal. This signal is negatively fed back to the power supply controlling the PZT attached to M2, and the cavity length is thus controlled to attain a continuous lock.

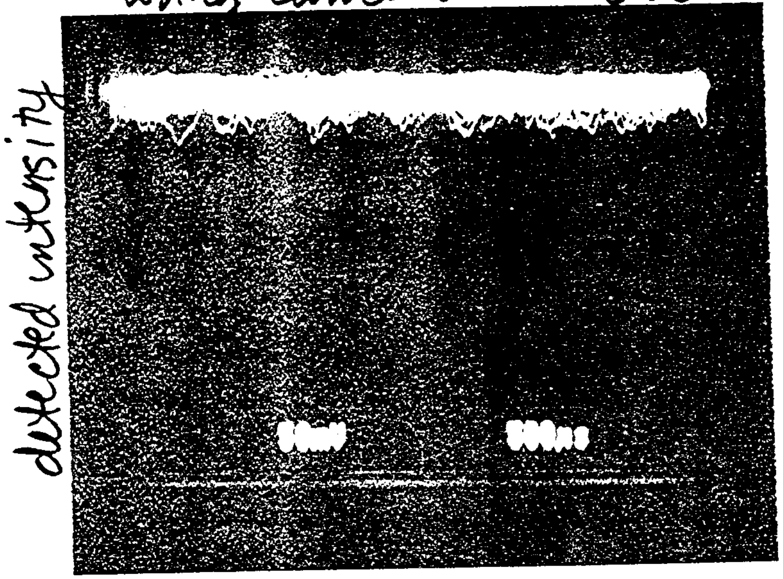


The PZT is sensitive to 1.5 kHz acoustic noise caused by a turbo-molecular pump operating in our laboratory, since the cavity is not yet acoustically or vibrationally isolated. We have used the negative feedback, loop to cancel this signal.

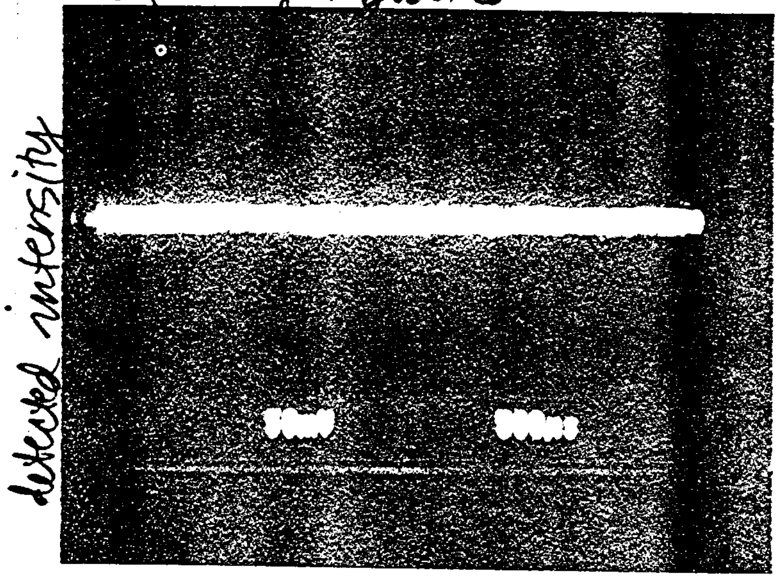


A microphone attached to the lab table near the turbo pump picks up the 1.5 kHz signal. This is added to the input to the PZT power supply with appropriate phase and gain to cancel the acoustic signal. We observe ~60% reduction in 1.5 kHz noise on the intensity of light leaking through the high reflector M3 with this cancellation scheme.

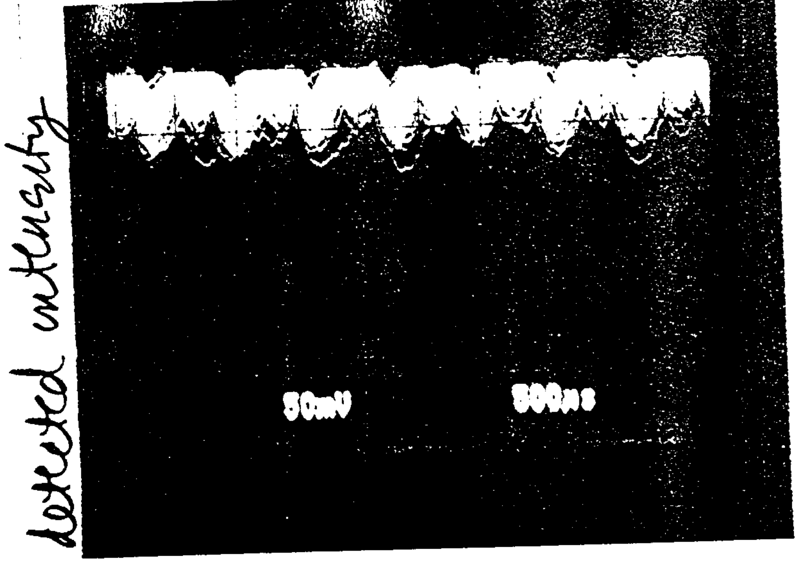
using cancellation circuit



input light blocked



without cancellation circuit



RESULTS

Using a Ti:Sapphire laser for evaluation of our system, we have obtained the following results:

input power @738nm (mW)	Uv output power (μW)	cavity buildup factor	uv conversion efficiency
10	63	25	0.0063

FUTURE PLANS

We will continue to optimize our cavity doubling system by improving both mechanical and optical considerations. The 738.8 nm diode laser can then be used to generate 369.4 radiation. The frequency of this light will be locked to the appropriate transition in a Yb hollow-cathode lamp, and it will then be used in the trapped ytterbium ion frequency standard.