PUMP LINEWIDTH REQUIREMENT FOR OPTICAL PARAMETRIC OSCILLATORS*

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ABSTRACT

A pumping laser at 0.473μ having a bandwidth of about 4 cm^{-1} has been used to construct a parametric oscillator having a bandwidth of about 1/4 cm^{-1} and tunable from about 2.45μ to 3.2μ . It is shown that for such an oscillator there is a significant advantage in resonating the I-R wave instead of the visible wave.

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It has been shown that singly resonant optical parametric oscillators have far greater spectral stability then the previously constructed doubly resonant oscillators.[1,2,3,4] The present Letter shows that, in addition, such singly resonant oscillators may be constructed using a relatively broad band multi-mode pumping laser, and still yield a narrow band spectral output. In particular a 4 cm^{-1} wide pump at 0.473μ has been used to construct a parametric oscillator having a 1/4 cm^{-1} wide spectral output tunable from 2.45μ to 3.2μ .

We consider the case where the signal frequency is fixed by the optical resonator and interacts with a broad band pump to generate a non-resonant broad band idler. The allowable pump bandwidth such that all modes of the pumping laser act in unison to produce gain is determined by the allowable momentum mismatch $\Delta kL \cong \pi$, where L is the length of the nonlinear crystal. For this case, the momentum mismatch Δk due to a pump bandwidth $\Delta\omega_p$ is given by

$$\Delta k = \left(\frac{\partial k_p}{\partial \omega_p} - \frac{\partial k_i}{\partial \omega_i} \right) \Delta\omega_p \tag{1}$$

and thus the allowable pump bandwidth is approximately

$$\Delta\omega_p = \frac{\pi}{L} \frac{1}{\frac{\partial k_p}{\partial \omega_p} - \frac{\partial k_i}{\partial \omega_i}} \tag{2}$$

As a result of normal dispersion $\Delta\omega_p$ is significantly larger if the free or non-resonated frequency is the frequency nearest to the pump. For the case of $LiNbO_3$ with a pump at 0.473μ , the signal and idler frequencies at 0.569μ and 2.79μ , respectively, evaluation of Eq. (2) using the Sellmeier equations for $LiNbO_3$,[5] indicates that the allowable pump bandwidth is about six times larger if the I-R frequency is resonated as it is if the visible frequency is resonated.

For our 3.2 cm $LiNbO_3$ crystal the allowable pump bandwidths are $\Delta\omega_p$(visible resonant) = 0.98 cm^{-1} , while $\Delta\omega_p$(I-R resonant) = 5.8 cm^{-1} . The spectral envelope of the doubled 0.946 line of our Nd:YAG pumping laser is about 4 cm^{-1} . Thus all the pump power should be effective in driving an oscillator which resonates the I-R wave, while only about one-fourth of the pump spectral power would be available to an oscillator resonating the visible wave.

A singly resonant parametric oscillator which resonated the I-R wave was successfully built. Figure 1 shows the spectral envelopes of the pump, non-resonant visible wave, and the resonant I-R wave as measured by a 1 meter

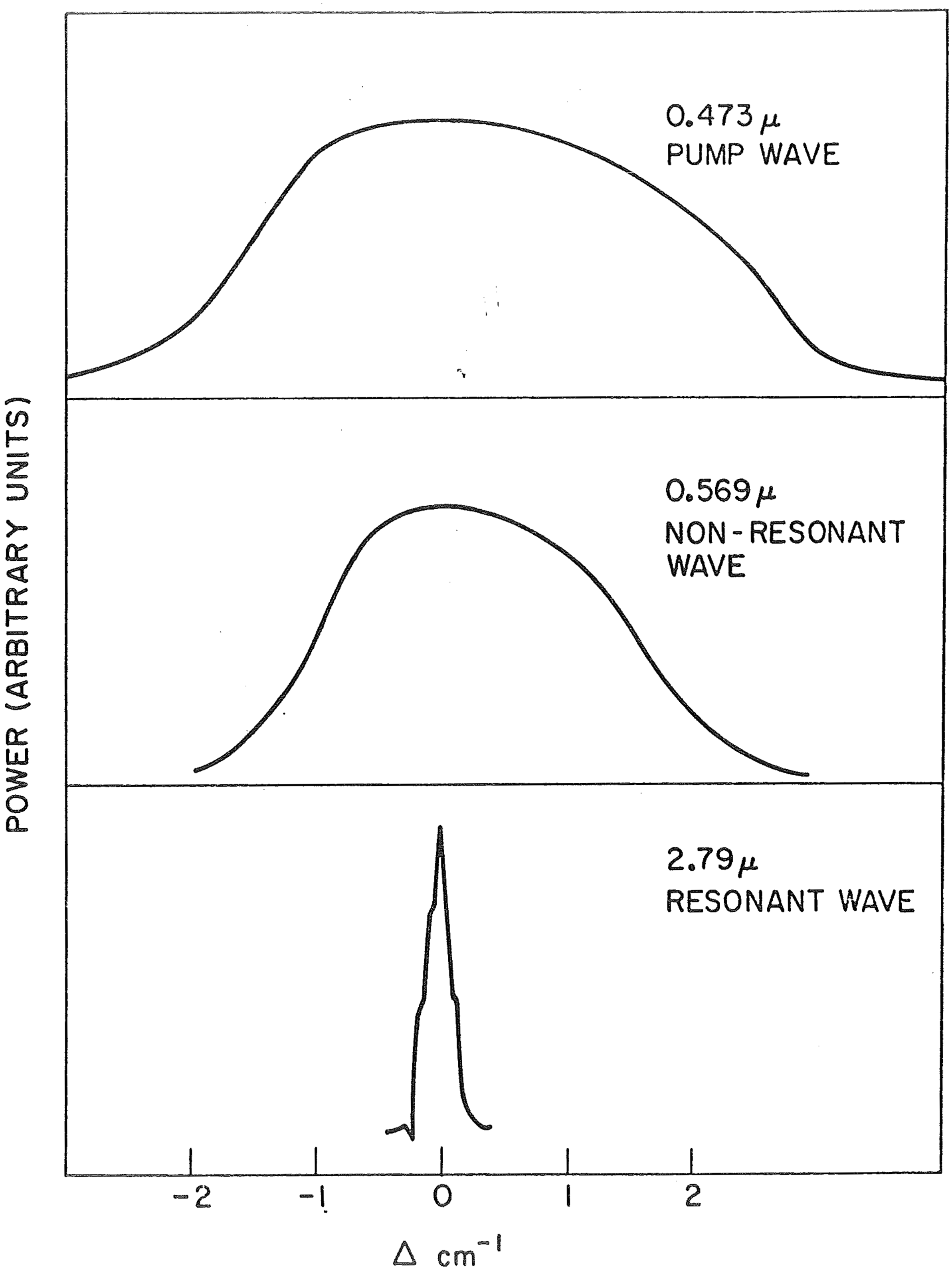

FIG. 1--Spectra of pump, non-resonant wave, and resonant wave.

Spex spectrometer having a resolution of about 0.4 cm^{-1} in the visible, and 0.1 cm^{-1} in the I-R . The spectrometer scan rate and the oscillator pulse rate were adjusted so that about 50 pulses were averaged within each resolvable frequency interval. As expected, the free idler has picked up the width of the pump while the resonated idler remains quite narrow. In general, the oscillator operated very stably with excellent pulse-to-pulse reproducibility, and a conversion efficiency of pump to tunable radiation of about 50% .[6]

An attempt to construct an oscillator which resonated the visible wave was unsuccessful until an internal etalon was used to narrow the laser spectrum. Even then the oscillator was only marginally above threshold and operated erratically at low power.

This work has thus shown that when constructing a singly resonant optical parametric oscillator with a relatively broad band pump, a significant advantage can be obtained by choosing the resonated wave to be that which is furthest in frequency from the pump. By using an etalon[2] inside the parametric oscillator cavity, still narrower I-R outputs will be obtainable; and will again utilize the full power of the relatively wide band pumping laser.

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