therefore not the limiting factor for imaging details of the sample surface. At a given electron current density, the available gain of the multiplier bundle will determine the maximum magnification possible.

In Fig. 2 the image of another freshly cleaved LiF crystal is shown. Figure 3 is the photograph of this sample. A 3-h x-ray exposure was used to fill the traps. The cleavage step across the center is 176-μ high. The thicker part of that crystal emits less electrons at any temperature. Therefore, the difference in brightness between the upper and the lower part of the image in Fig. 2 cannot be caused by a possible temperature difference. An interesting feature of the EEE image in Fig. 2 is the circular spots of very low emission in the lower left corner. They could not be interpreted as "blind" spots of the multiplier bundle and therefore must be areas of either high work function, low trap density, or both. These and certain other structures of the EEE images could not be related to any visible structures on the surface. This demonstrates that not only macroscopic defects but also microscopic defects and other invisible property differences of various parts of the surface influence exoelectron emission. It is hoped that EEE imaging will provide a new tool for the study of surface properties of a dielectric solid.

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Pump Linewidth Requirement for Optical Parametric Oscillators*

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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.[1–4] The present letter shows that, subject to a restriction on the pump linewidth, such singly resonant oscillators may be constructed using a broadband multimode pumping laser, and still yield a narrow-band spectral output. In particular a 4-cm^{-1}-wide pump at 0.473 μ has been used to construct a parametric oscillator having a $\frac{1}{4}$-cm^{-1}-wide spectral output tunable from 2.45 to 3.2 μ.

We consider the case where the signal frequency is fixed by the optical resonator and interacts with a broad-band pump to generate a nonresonant 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

$$\Delta k = [(\partial k_p/\partial\omega_p) - (\partial k_i/\partial\omega_i)]\Delta\omega_p \qquad (1)$$

and thus the allowable pump bandwidth is approximately

$$\Delta\omega_p = (\pi/L)\{[(\partial k_p/\partial\omega_p) - (\partial k_i/\partial\omega_i)]^{-1}\}. \qquad (2)$$

As a result of a normal dispersion $\Delta\omega_p$ is significantly larger if the free or nonresonanted frequency is the frequency nearest to the pump. For the case of $LiNbO_3$ with a pump at 0.473 μ, the signal and idler frequencies at 0.569 and 2.79 μ, 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 IR frequency is resonated than it is if the visible frequency is resonated.

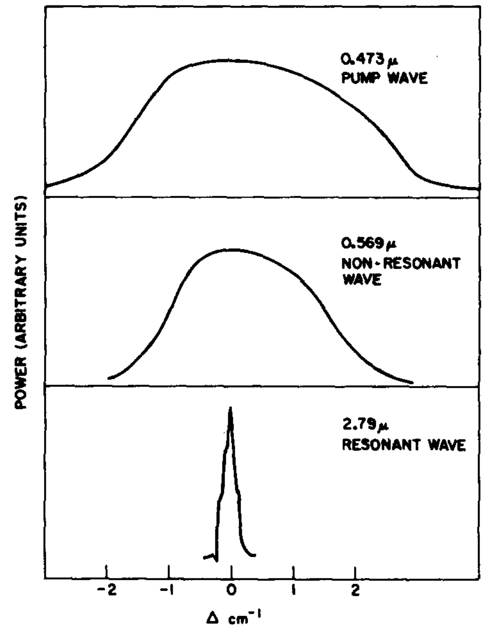

FIG. 1. Spectra of pump, nonresonant wave, and resonant wave.

For our 3.2-cm $LiNbO_3$ crystal the allowable pump bandwidth is $\Delta\omega_p$ (visible resonant) = 0.98 cm^{-1}, while $\Delta\omega_p$ (IR 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 IR 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 IR wave was successfully built. The oscillator was pumped with 0.473-μ radiation obtained by internally doubling the 0.946-μ line of Nd:YAG. Peak power and pulse length at 0.473 μ were about 2 kW and 400 nsec, respectively. Figure 1 shows the spectral envelopes of the pump, nonresonant visible wave, and the resonant IR wave as measured by a 1-m Spex spectrometer having a resolution of about 0.4 cm^{-1} in the visible, and 0.1 cm^{-1} in the IR. 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 broadband 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 IR outputs will be obtainable and will again utilize the full power of the relatively wide band pumping laser.

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Characteristics of "Before Glow" on a Thermoluminescent Glow Curve as a Tool in the Investigation of Point Defects in α-Quartz

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The characteristics of "before glow" on the thermoluminescent glow curve produced by a γ-irradiated radiation sensitive (type 1)[1] α-quartz sample were examined for the applicability as a tool for clarifying the properties of point defects in the crystal.

Since the electrons in the conduction band freed from the shallow traps in a thermoluminescent phosphor have small activation energies with shorter lifetimes than the order of 10^{-8} sec, they tend to be retrapped easily by nonuniformity of the heating rate, where the rate is in such a range as to make $dT/dt \geq 0$, so that this effect is most pronounced at beginning of a glow curve run.

In the low-temperature region during the initial stage of a glow curve, the average energy of the conduction band electrons may be a bit higher than the average demarcation level for the electrons; also the radiation-induced point defects will have a higher capture cross section for the free electrons.

Generally, a "before glow" is yielded at about half of the peak temperature of the principal glow after some lapse of time from the glow start if the heating rate is nonuniform from the beginning. Probably, a group of conduction band electrons having disrupted a supply of constant thermal energy due to nonuniformity of the heating rate, wander in the conduction band by exchange of their energies, and at a critical mean energy level, retrapping occurs similar to an avalanche of electrons. Such triggered retrapping is caused partly by the nature of a phosphor crystal having the most shallow traps among the trapping centers, and also partly by the electrons trapped in the most shallow trapping levels of the trapping centers.

Gamma-ray energies can be reduced by back scattering due to Compton process at the shielding wall in the irradiation room. The energy changes of photons depend upon the scattering angles due to the geometry of the room and the scattering cross section of the shielding materials.

Although the γ energy of direct irradiation is almost constant regardless of distance x from the source, however, in proportion as the increase of x to a certain extent, it seems that the ionizing radiation due to the γ rays of reduced energies is gradually predominant. For this, the arrangement of the source, sample, shielding, and the wall in irradiation room should be taken into account. It should be evident that, during the irradiation of a phosphor sample, the released electrons due to γ rays of reduced energies will be trapped on the shallower traps than the electrons released by the γ rays of unreduced energies.

This effect has been examined by γ-irradiated type 1 α-quartz samples as shown in Fig. 1. All glow curves in Fig. 1 were produced by K point (a point near the saturation temperature) cutoff method,[2] and the time was marked on the chart paper by interrupting the *PM* tube power supply. The heating system of the reader depends on a spontaneous linear rise in temperature due to the heat capacities of the furnace and the sample at a predetermined heater voltage with evacuated environment, and the detail is described in Ref. 2.

It is shown in Fig. 1 that the effective peak height h_b (cf. Fig. 2) on the glow curve of the lowest dose rate is highest among the glow curves as shown in Fig. 1. This means that the cause of "before glow" is greatly related to the γ rays of reduced energies, i.e., the highest h_b of the "before glow" was produced possibly by the dominant retrapping of the conduction band electrons released from the shallowest traps in the quartz sample. Mitchell and Paige[3] have suggested the presence of a conduction band in crystalline quartz.

It is denoted that the characteristics of the "before glow" may have some promising applicability as a tool for clarifying the properties of point defects in the quartz crystal, and can be explained by an illustration shown in Fig. 2.

In Fig. 2, B, D, and F are inflection points, and $I_C - I_B$ is an effiective height (h_b). The rising slope $dI/dT|_B$ and h_b in each glow curve in Fig. 1 are inversely proportional to the dose rate. It is observed that the angle of the down slope $dI/dT|_D$ and the rising slope to the principal glow $dI/dT|_F$ are proportional to the dose rate. It is assumed that $dI/dT|_D$ can increase up to positive infinity with the increase of the dose rate and the variation of $dI/dT|_B$ and $dI/dT|_F$ is always greater than zero and less than positive infinity.

These characteristics of the "before glow" may give some qualitative and quantitative informations of the properties of point defects in the quartz crystal. In case of the similar dose rate and dose of two different species of the quartz samples, it is evident that the difference of $dI/dT|_B$, $dI/dT|_D$, $dI/dT|_F$, and h_b will show the different properties of point defects in both crystals.

If the ${}_xP_-$ and the ${}^{41}A_+$ defects are homogeneously distributed in the one sample without clusters, $dI/dT|_B$ and h_b will become larger than those of the other sample, but on the contrary, if the one sample includes regionally radiation insensitive (type 2)[1] α-quartz having the clusters of ${}_xP_-$ and ${}^{41}A_+$ defects, twinnings, and dislocations, $dI/dT|_B$ and h_b will be greatly decreased compared to those of the other sample. The h_b probably denotes a barometer of the number of electrons participated for the retrapping. The slope $dI/dT|_D$ is mainly related to the state of

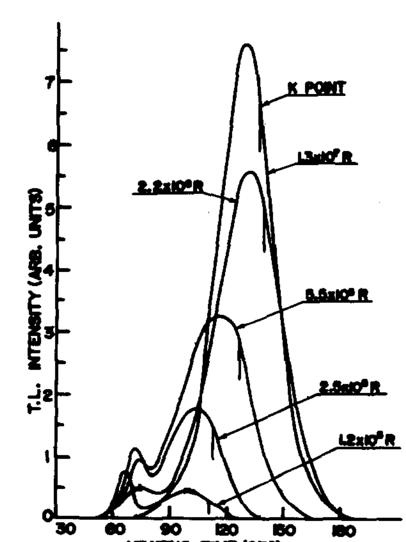

FIG. 1. Dose and dose rate dependence of glow curves due to γ-irradiated type-1 α-quartz samples.