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Printed July 1998

Transient Radiation Effects in D.O.I. Optical Materials: KD*P

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Abstract

Department of Energy and Defense Programs systems are becoming increasingly reliant on the use of optical technologies that must perform under a range of ionizing radiation environments. In particular, the radiation response of materials under consideration for applications in direct optical initiation (D. O. I.) schemes must be well characterized. In this report, transient radiation effects observed in a KD*P crystal are characterized. Under gamma exposure with 2 MeV photons in a 20-30 nsec pulse, we observe induced absorption at 1.06 μm that causes a peak decrease in overall sample transmittance of only 10%. This induced loss is seen to recover fully within the first 30 μsec.

Acknowledgments

The author acknowledges the support of the Hermes III operations crew and Dorothy Meister for their assistance in performing the experiments. This work has been supported by the United States Department of Energy under Contract DE-AC04-94AL85000.

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Introduction

Department of Energy and Defense Programs systems are becoming increasingly reliant on the use of optical technologies that must perform under a range of ionizing radiation environments. While the radiation response of some passive components and systems has been investigated, the transient radiation response of new, multi-component laser materials, thin films, filters and active and passive non-linear materials is largely unknown. In this report, we examine the gamma-induced, transient radiation response of KD*P crystals at 1.061μm.

Potassium dideuterium phosphate, KD*P (KD_2PO_4), is a strongly non-linear inorganic crystal[1-3] that is commonly used as an optical frequency doubler and is transparent across wavelengths in the visible and the near infra-red. It is unique in that it undergoes an irreversible phase transition at elevated temperatures. As such, the material has potential for use in optical safety schemes relevant to D. O. I. initiatives. In the case where the material is required to pass a pump wavelength, it is particularly important to characterize the effects of radiation environments on the transmittance of the crystal at the pump wavelength.

It is well know that defects of crystal structure can give rise to numerous effects including changes in electrical conductivity, photoconductivity, optical absorption and optical luminescence[4-6]. Point defects and point defect complexes originate from many sources including atomic displacement, which creates vacancy-interstitial pairs, and electron rearrangement, which forms diamagnetic and paramagnetic defects with unique absorption and luminescence characteristics. In the presence of high-energy photons, such as x-ray or gamma-ray radiation, it is reasonable to predict that incoming photons will excite such electronic defects, giving rise to transient and/or permanent changes in the absorption and luminescent band structure of the crystalline material under test.

Experimental Methods

Ionizing radiation exposures were conducted at the Hermes III accelerator facility at Sandia National Laboratories, Albuquerque. Gamma pulses of approximately 2 MeV photons were delivered in pulses averaging 20 nsec in duration. The average dose per shot at the samples was 80 krad and the evolution of radiation-induced fluorescence and absorption signals was observed over a time frame ranging from 1 μsec to 10 msec. The experimental set-up is shown in figure 1. Samples and collimating optics were placed on a 4-ft. by 2-ft. optical breadboard in the test cell for the exposures. Optical fibers, shielded from the gamma source by 2 to 4 inches of lead shielding, were used to bring optical signals into and out of the test cell. Data were collected in a separate screen room outside of the test area with optical signals being delivered by the 25-meter long fiber cables. As can be seen in figure 1, radiation from a Lightwave Technology Model 124D-GSGG laser was coupled into several optical fibers that carried the light into the test cell. The laser is a diode-pumped ring laser with a neodymium-doped gadolinium scandium gallium garnet (GSGG) laser rod oscillating single mode at 1.061 μm. Collimators out-coupled the light from the fibers, allowing it to propagate down the length of the table and pass through the selected samples to retroreflectors. Reflected light propagated back through the samples to the collimator optics where it was coupled back into the fiber. Beam splitters on the optical bench located in the screen room directed the returned optical radiation onto two photodetectors. Noise error arising from the detection of room light was minimized by aligning 1.061 μm interference filters in front of the detectors. Samples of KD*P crystals were placed in the test cell and transient radiation-induced loss signals were observed. Sample thicknesses were nominally 4 mm. Given the double pass geometry of the optical path (see figure 1), the optical thickness was about 8 mm for each sample. Data acquisition was achieved using Hewlett Packard transient digitizers connected to the detector outputs shown in figure 1. The halogen lamp shown in the experimental set-up in figure 1 was not used in this series of tests on these samples.

Results and Discussion

Figures 2 and 3 show the effects of ionizing radiation on the transmittance of the KD*P at 1.06 μm. The data in these figures has been corrected for spontaneous emission and induced absorption in the fiber cables and collimating optics. In figure 2 we clearly observe an induced loss signal immediately following the gamma pulse. This induced loss reaches a maximum of a 10% decrease in the optical transmittance of the samples. The optical transmittance is seen to grow quickly (figure 3) after this initial induced loss such that the sample transmittance has fully recovered within the first 30 μsec after the gamma-radiation pulse. A maximum induced absorption coefficient of 0.132 cm^{-1} has been calculated. This is a fairly large absorption coefficient in an optical material and illuminates the point that the initial observed induced loss at 1.06 μm is slight due in large part to the small thickness of the samples.

Conclusions

We have shown that KD*P has a moderate transient response to ionizing radiation which completely recovers within 30 μsec. These results indicate that KD*P has superior transient radiation hardness and would be an excellent candidate for an optical element in both safety schemes and laser designs requiring reliable performance in high radiation fields.

References

1) M. J. Weber, Handbook of Laser Science and Technology, Supplement 2: Optical Materials, CRC Press (1995).

2) R. W. G. Wyckoff, Crystal Structures, 1-5, 2nd ed., Interscience, New York (1960).

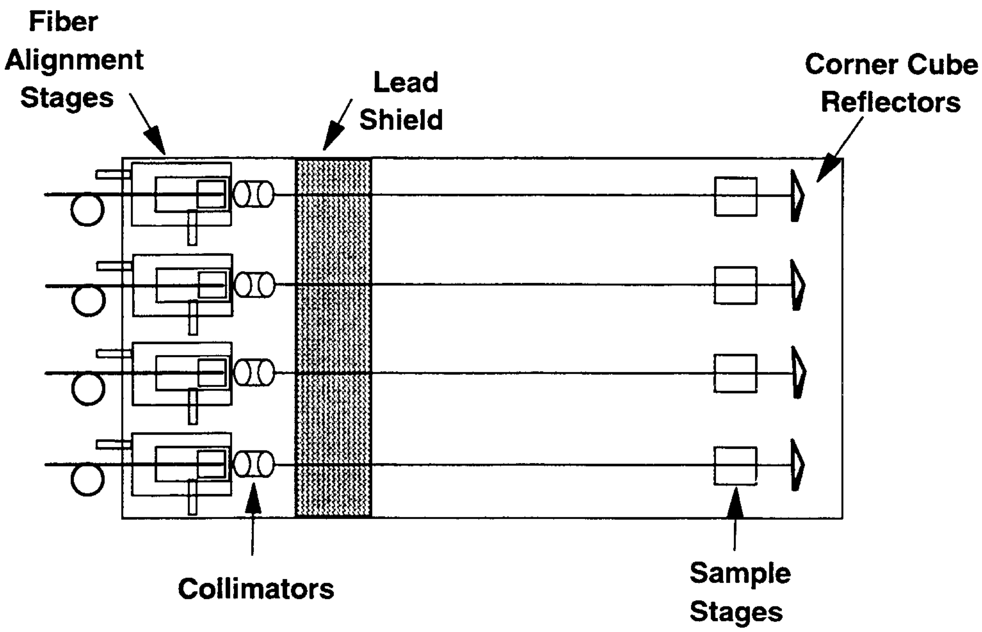
3) R. C. Weast, CRC Handbook of Chemistry and Physics, CRC Press, Boca Raton, FL (1993).

4) D. L. Griscom, "Nature of Defects and Defect Generation in Optical Glasses," SPIE 541, Radiation Effects in Optical Materials, 38 (1985).

5) L. T. Chadderton, Radiation Damage in Crystals, John Wiley and Sons, New York, NY (1965).

6) K. Nassau, The Physics and Chemistry of Color, John Wiley and Sons, Inc., New York, NY (1983).

Figures



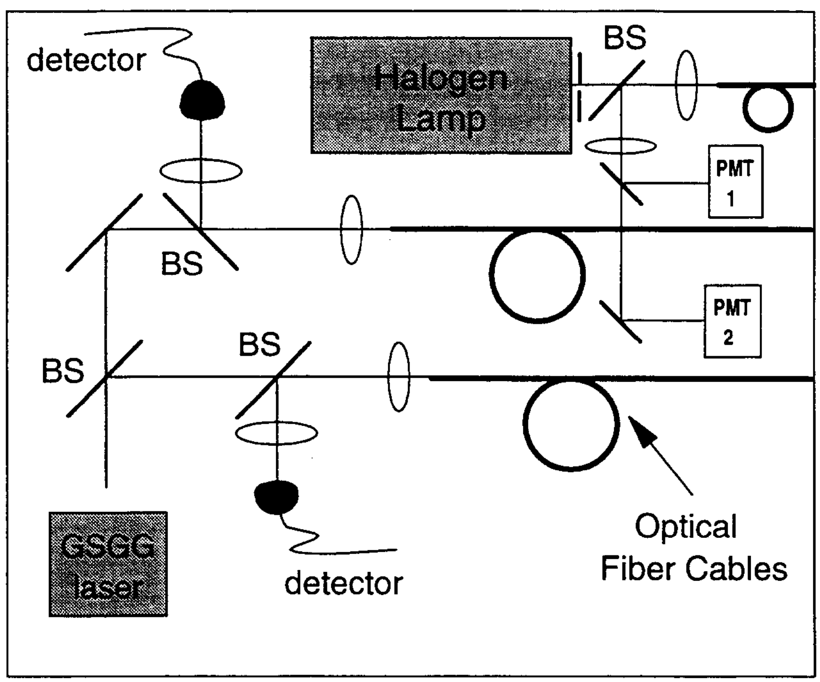


Figure 1: The upper optical bench holds the test samples and is located in the test cell. Optical signals are carried into the shielded screen room by 25 m fiber cables. Transient radiation-induced absorption signals are recorded using the PMTs and photodetectors. Filters in front of the infra-red photodetectors help reduce the noise signal originating from room lights.

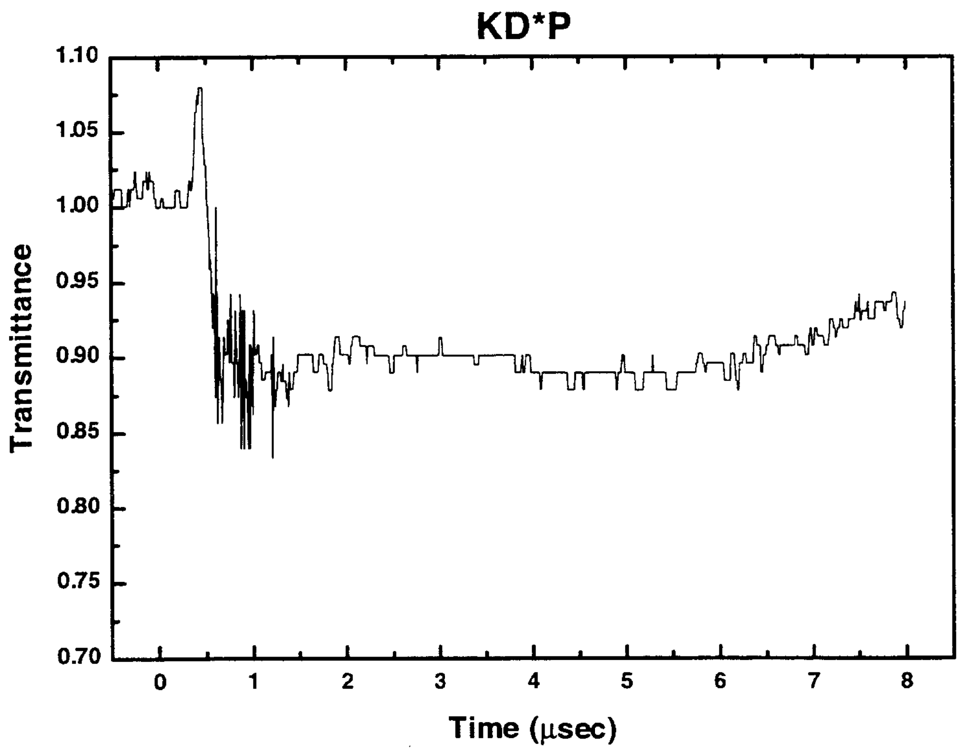


Figure 2: Transient radiation-Induced optical absorption in KD*P at 1.061 μm.

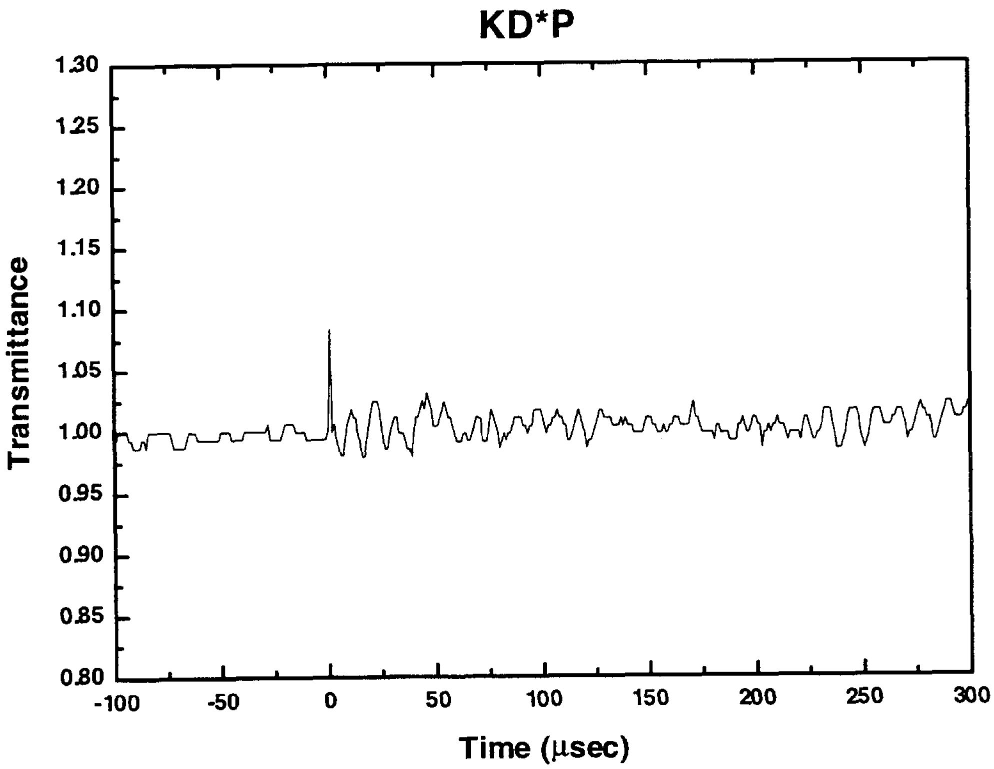


Figure 3: Transient radiation-induced optical absorption in KD*P at 1.061 μm.

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