Toward the Reduction of Transverse Stimulated Raman Scattering in KDP/DKDP Crystals

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Transverse Raman generation and amplification in KDP/DKDP limit the laser power level in laser fusion systems. To properly understand the propagation and amplification of light in a birefringent crystal, a full vector model of the pump and scattering fields is required. We present a ray-tracing approximation that enables one to calculate the Raman fluence at the surface of an arbitrary crystal and pump polarization configurations. This allows one to determine the optimal configuration that minimizes the fluence peaks at the crystal edge.

Raman photons can be generated by the strong laser field (the pump) in a piece of thin crystal placed perpendicular to the path of the pump (Fig. 1). Depending on the crystal symmetry and orientation, such a signal may have significant accumulated gain when traveling parallel to the plate due to the long length of travel inside the crystal. Such transverse Raman rays have the potential to gain more energy than those parallel to the pump direction that have less distance for amplification.

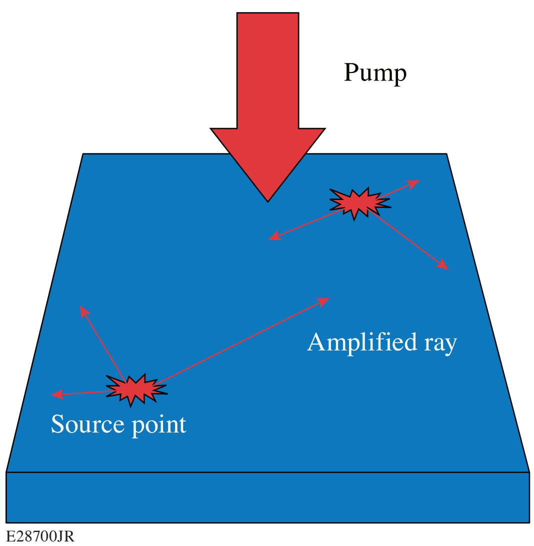

Figure 1
The pump laser excites spontaneous Raman photons in a laser crystal. The Raman is amplified as it propagates in the crystal.

The distribution of the transverse stimulated Raman scattering (TSRS) fluence at the crystal surface is not uniform. It depends on the pump laser and crystal configurations. The fluence at a surface point is the sum of all the amplified rays that arrive at this location. To calculate such fluence requires ray tracing of each such ray over the path from the spontaneous emission source point to the surface point. This requires a rigorous treatment of the ray propagating in a birefringence crystal.

The starting point of our modeling is to break each ray into the normal modes of electromagnetic waves, i.e., the o and e polarizations; similarly the pump is also broken into o and e polarizations. The Raman gain can therefore be treated as the combination of interactions between these normal modes.

An efficient code was developed following the picture of basic physics shown in Fig. 2. We were able to calculate the fluence distribution at the crystal surface for any laser and crystal configuration, including the crystal thickness and beveled-edge angle. From these calculations we can estimate the maximum laser intensity without damaging the crystal and mount, providing a guideline for the optimized crystal configuration. For example, in Fig. 3 we can see the worst-case intensity depends on the pump polarization. By selecting the correct crystal cut direction, the worst-case intensity at the crystal plate edge can be reduced.

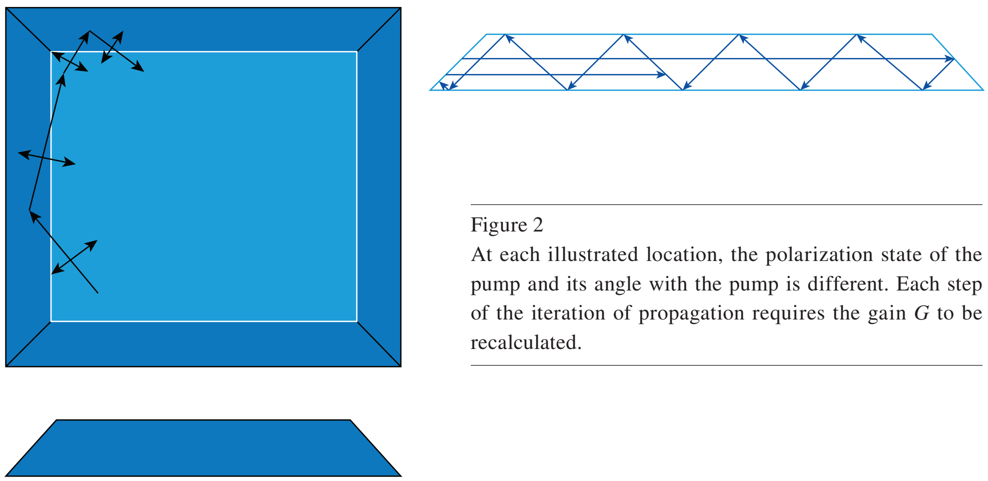

Figure 2
At each illustrated location, the polarization state of the pump and its angle with the pump is different. Each step of the iteration of propagation requires the gain G to be recalculated.

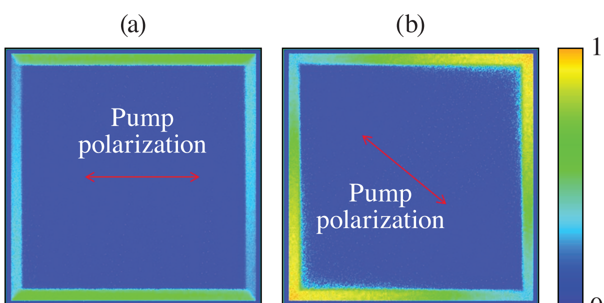

Figure 3
These plots show that the Raman distribution at the crystal surface depends on the pump polarization. (a) Pump polarization normal to the optic axis. (b) Pump polarization at an angle to the optical axis.

In summary, TSRS in laser crystal is a phenomenon we cannot completely avoid but we can find solutions to reduce the worst-case fluence at the crystal edge to avoid component damage. The key to finding such solutions is to distribute the Raman energy incoherently over polarizations and directions. The ray-tracing methods we developed provide a better understanding about how the evolution of polarization states in the crystal affect the TSRS and are a versatile tool to optimizing the design of KDP/DKDP optics including the distributed polarization rotator.

This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0003856, the University of Rochester, and the New York State Energy Research and Development Authority.