Title: USING OPTICAL PARAMETRIC OSCILLATORS (OPO) FOR WAVELENGTH SHIFTING IR IMAGES TO VISIBLE SPECTRUM

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Using Optical Parametric Oscillators (OPO) for Wavelength Shifting IR Images to Visible Spectrum

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ABSTRACT

We have carried out preliminary investigations into coherent imaging using Optical Parametric Oscillators (OPO) for wavelength conversion of near IR images to visible spectrum. A nonlinear crystal, second harmonic generator (SHG), was used for degenerate optical parametric up-conversion. A Potassium Titanyl Phosphate (KTP) doubling crystal was used to convert incident 1540nm flux to 772nm. Experiments included investigation of spatial resolution and responsivity of the OPO. Spatial resolution of 1.3 lp/mm was attained in both horizontal and vertical axis. Measured responsivity for this OPO configuration compared well with that attained from image intensifier-based systems. Equipment used for this experiment included an ORION SB2-2R pulsed solid state laser used as a light source and a CCD camera and frame grabber to capture and record all data. The experiment and results are discussed.

BACKGROUND

Imaging in the near IR is a goal of some projects that are being carried out at the Los Alamos National Laboratory under the joint Department of Energy and Department of Defense technology development program. Such a capability is useful in a number of applications including LADAR and range gated imaging. We have specifically been investigating range gated imaging in the region of 1.5 microns wavelength, where the eye damage threshold is 3 to 4 orders of magnitude higher than that at the shorter wavelengths from about 1.2 microns into the visible (Ref. 1).

The fundamental difficulty in imaging at 1.5 microns is the lack of photocathode materials that can detect 1.5-micron photons. Whereas photocathode materials have been developed that can detect photons over the wavelength range of approximately 100 to 1200 nm (Ref.2), the energy in a 1.5 micron photon is too low to stimulate photoemission in currently available photocathode materials. Alternate detection approaches must be found if imaging is to be possible at the 1.5 micron wavelength. One possible approach that has been developed with a degree of success is referred to as transferred electron (TE) photocathode, which was conceived and patented by Bell in the 1970's (Ref. 3) and within the past few years further developed by Intevac Advanced Technology Division of Santa Clara, CA. (Ref. 4) Although details of the Intevac development are propriety, basically the transferred electron photocathode approach uses an externally applied electric field to increase the energy level of excited electrons sufficiently to escape into the vacuum region of the intensified.

We have conducted several range gated imaging experiments using visible wavelength photocathodes (Ref. 5). Our earlier unpublished studies investigated the use of the Intevac TE photocathode intensifier in a planar diode configuration coupled to our own high speed stripline image intensifiers (Ref. 6). This combination would exploit the IR sensitivity of the TE photocathode and the fast shuttering capabilities of the stripline geometry intensifiers.

An alternate approach that is being considered by us at Los Alamos is the use of nonlinear optical crystals to double the frequency (or half the wavelength) of the 1.5 micron return signal to produce a signal in the region of 750-micron that can be detected by conventional photocathodes or CCD cameras. This approach of frequency doubling, or second harmonic generation, is commonly used to produce the second or third
harmonic wavelengths of a laser beam from a fundamental, such as the production of a 532 nm beam from a 1064 nm Nd:YAG laser. In this investigation we are considering whether a nonlinear crystal could also be used to up-convert 1.5-micron laser light returned from a target in a gated imaging system and be detected by a CCD camera or a conventional image intensifier. Issues to be considered include flux density into the nonlinear crystal, which affects conversion efficiency and output signal strength, light acceptance angle, which defines the system field of view, and spatial information invariance through the conversion process. Our first experiment was to determine if the spatial information (the image data) in the incoming signal remained undistorted through the nonlinear conversion process.

EXPERIMENTAL SETUP

A laboratory laser, the ORION SB2-2R, manufactured by MPB technologies, Inc. of Dorval, Quebec, Canada, was used to observe imaging through a nonlinear optical crystal. In the ORION laser, the fundamental laser beam is produced by a Nd:YAG oscillator, which generates an 8ns, 30mJ pulse at 1064nm wavelength. Up to 6 different beams of differing frequencies and pulse widths are produced by routing the fundamental beam through various stimulated Brillouin and Raman cells and nonlinear optical crystals. The beam we used for our imaging experiments had a pulse width of 20ps at a wavelength of 1540nm. The beam is routed through a nonlinear optical crystal, a KTP (Potassium Titanyl Phosphate) second harmonic generator, to produce a 772nm wavelength beam.

A bar pattern of approximately 1.3 lp/mm was placed in front of the KTP second harmonic generator crystal and a CCD camera was placed behind the crystal in order to observe the spatial modulation of the beam produced by the bar pattern through the crystal. A schematic diagram of the ORION laser showing the placement of the optical target pattern in given Fig. 1.

Fig. 1 Block Diagram of ORION laser showing location of 1.3 lp/mm bar pattern in the 1540nm beam line and location of CCD camera after the second harmonic generation nonlinear optical crystal.
EXPERIMENTAL RESULTS

Images were taken of the frequency doubled laser beam with the Cohu CCD camera and recorded using a Big Sky frame grabber. The recorded images are shown in Fig. 2a and 2b. The bar pattern used in these images had approximately 1.3 line-pairs/mm. Fig. 2a is taken with the lines running in a direction horizontal to the camera and Fig. 2b is taken with the lines running vertical to the camera. Although we observed fringe patterns in the images, spatial modulation is definitely maintained.

Fig. 2a Fig. 2b

Fig. 2 Image recorded by camera of Laser beam after the second harmonic generator crystal (1.54mm—772nm). Spatial frequency of the line pattern is 1.3 lp/mm. Figure 2a is with the pattern in the horizontal orientation and Figure 2b is with the pattern in the vertical orientation.

CONCLUSIONS

It appears that spatial modulation is maintained through the nonlinear crystal conversion process; however, a great deal of fringing and some distortion is present. Our next step in the assessment is to examine imaging at a low flux level and determine the lower practical bounds or the process.

REFERENCES

2. I. P. Csorba, Image Tubes, Howard W. Sams & Co., Inc.,
3. R. L. Bell, Long-wavelength Photoemission Cathode, Patent Number 3,958,143