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SCALING STUDIES OF EFFICIENT RAMAN CONVERTERS

H. Komine [redacted] J. B. West
NORTHROP CORPORATION
Northrop Research and Technology Center
One Research Park
Palos Verdes Peninsula, California 90274

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SCALING STUDIES OF EFFICIENT RAMAN CONVERTERS

SUMMARY

The objective of this program is to demonstrate the scaling potential of efficient Raman frequency conversion techniques for ultraviolet lasers. Molecular hydrogen is used as the Raman medium and an oscillator-amplifier configuration is employed to maximize conversion efficiency and beam quality.

At the present time, major program milestones have been successfully met. Injection locking has been demonstrated to be an efficient technique for laser bandwidth control. Good optical beam quality has been achieved on the XeF laser through the use of unstable resonator optics. Conversion of XeF laser radiation to blue-green wavelengths has been demonstrated in the Raman oscillator.

Work is now in progress on assembly of the Raman oscillator-amplifier system to complete the final phase of the program. It is expected that 50% energy efficiency will be demonstrated for the shift of 353 nm XeF radiation to 498 nm.

OBJECTIVE

The objective of this program is to demonstrate the scalability of efficient Raman frequency conversion techniques developed at NRTC. These techniques use molecular hydrogen as the Raman medium and employ an oscillator-amplifier configuration for the Raman frequency converter. A particular goal of this program is the demonstration of 50% energy efficiency for the shift of 353 nm XeF radiation to 498 nm (second Stokes shift).

DESCRIPTION OF PROGRESS

Small Scale XeF Injection Locking Experiments

Figure 1 shows the experimental layout of the small scale XeF injection locking experiment. The basic features were described in a previous report. A few changes have been made during the present reporting period. It was found that with oxazine 720, only a single slave dye laser is required, so one of the Candella SLL 625A lasers is no longer used. Also, doubling efficiency of the 706 nm radiation is improved by using a cylindrical lens to focus radiation on the KDP crystal.

Output from the coaxial e-beam XeF laser has been injection locked to a linewidth of 0.004 nm. Figure 2 shows the unlocked and locked spectrum of the XeF 353 nm band obtained from the photodiode array on the lm spectrometer. Figure 3 shows this same data replotted for greater clarity. In Figures 2 and 3 the linewidth observed is limited to about 0.04 nm by the instrument. The small maximum on the long wavelength side of the band in Figure 3 is due to a small amount of injected signal at that frequency from a second etalon mode in the CMX-4 master oscillator. Figure 4 shows a cross section through the central portion of a Fabry-Perot etalon ring pattern formed by the injection locked XeF laser. The etalon has a calculated finesse of 20 and a free spectral range of 1.7 cm^{-1}. Analysis of this Fabry-Perot spectrum indicates the actual locked laser linewidth is about 0.004 nm. In these experiments, the XeF laser energy was 80 mJ in a 140 ns pulse. The ratio of injected power to laser power was about 1:5000. By more appropriate spatial mode matching, further improvement in this ratio is expected. Measurements of pulse energies for both the locked and unlocked XeF laser indicates the efficiency for this process is at least 90%.

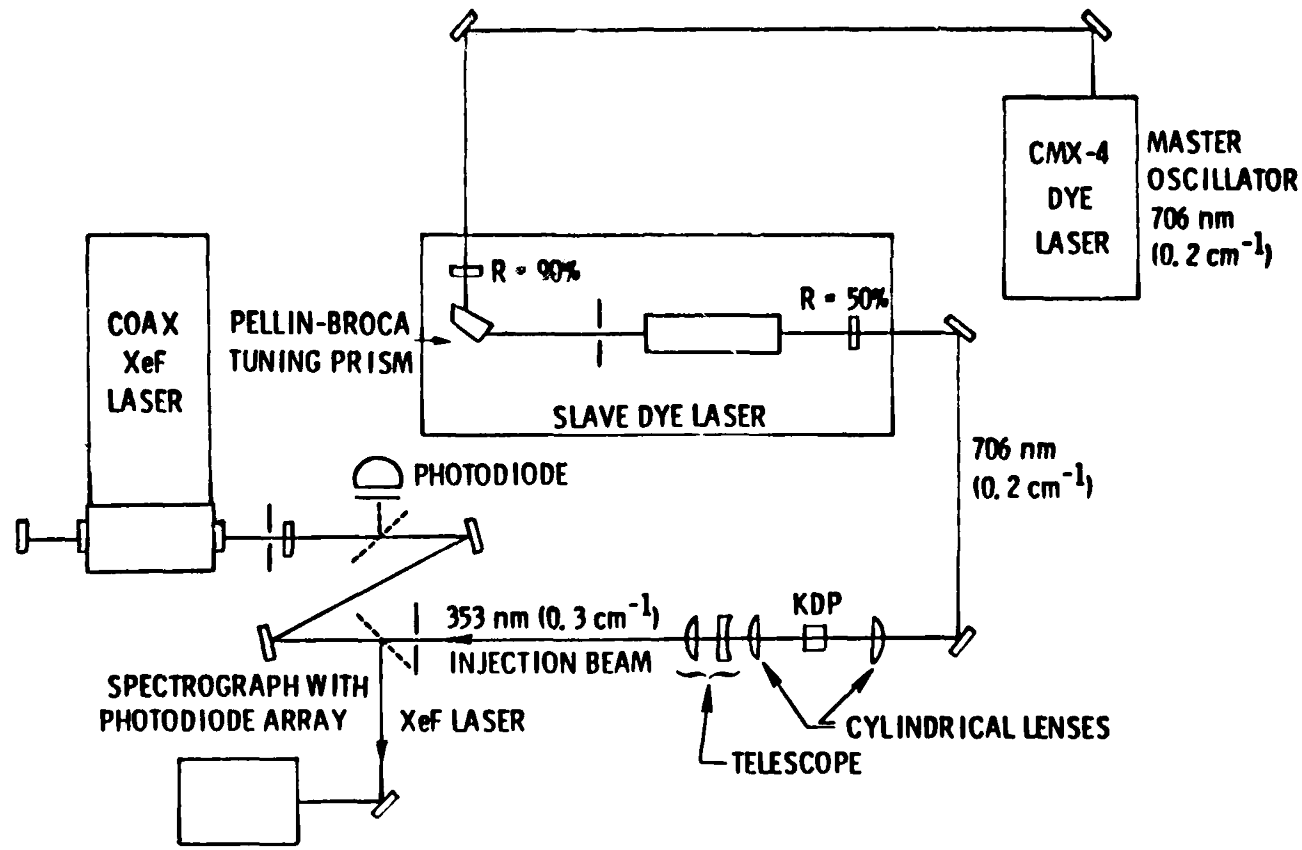
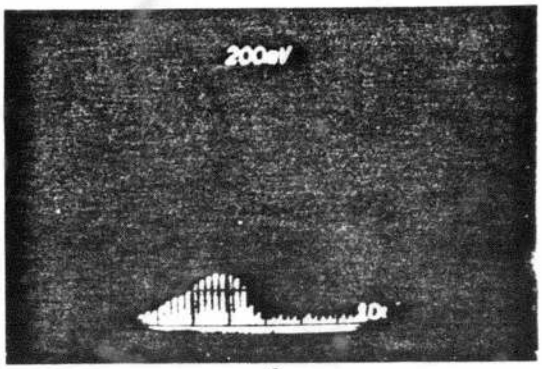
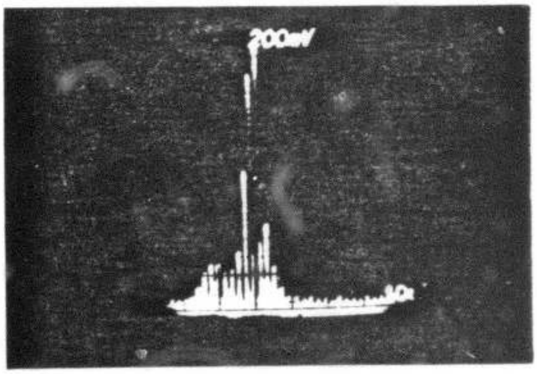


Figure 1. Coaxial XeF Laser Injection



(1.25 Å/DIV)

(a) XeF LASER 353 nm BAND SPECTRUM



(b) INJECTION-LOCKED XeF LASER SPECTRUM
(INSTRUMENT LIMITED RESOLUTION ≃ .4 Å FWHM)

Figure 2. Injection Locked XeF Laser Spectrum

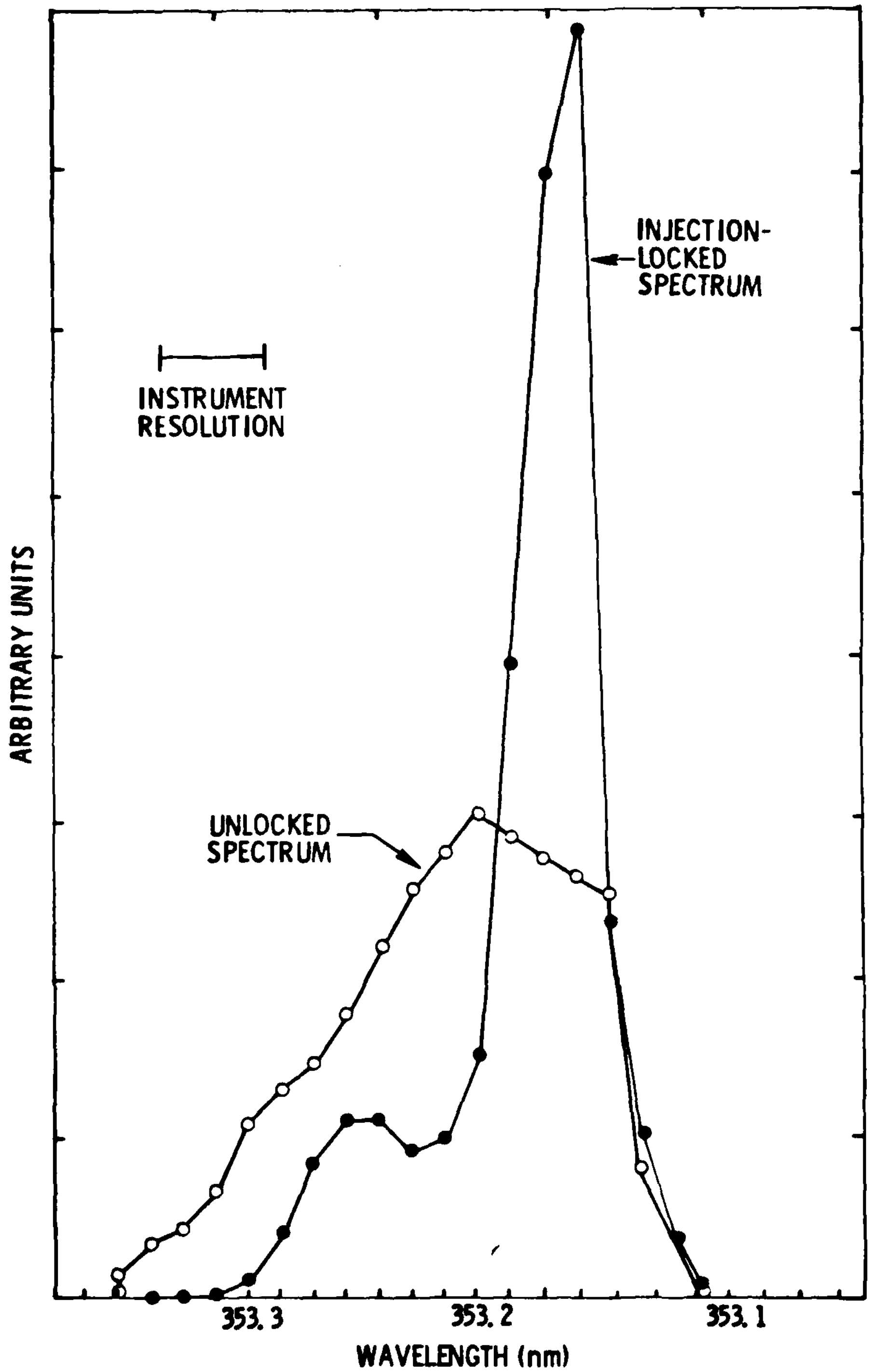
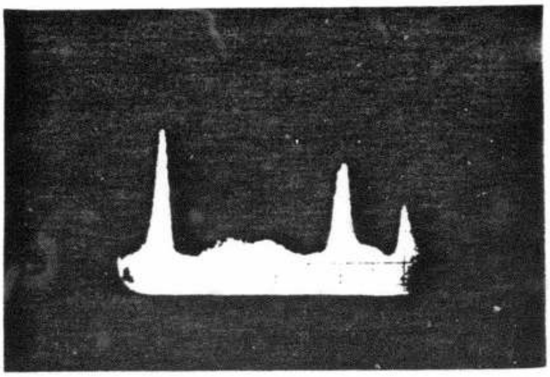


Figure 3. Injection Locked XeF
Laser Spectrum



LINEWIDTH MEASURED USING A SOLID FUSED SILICA ETALON

FREE SPECTRAL RANGE = 1.7 cm^{-1}

FINESSE $\simeq$ 20

$\Delta\nu \approx 0.3\ cm^{-1}$

$\Delta\lambda \approx 0.04\ Å$

Figure 4. XeF Linewidth Measurement Laser Injection Locked at 353 nm

SWAT Laser Injection Locking

Figure 5 shows the experimental setup used to perform preliminary injection locking experiments on the SWAT XeF laser. The uv injection source is the same as that shown in Figure 1. The XeF laser was operated with flat resonator optics, apertured to 3.8 cm diameter. As in the small scale experiments, the injection signal was coupled into the cavity through the output coupler.

The laser produced an 0.8 joule pulse, 1.2 μs long. With injection locking, the linewidth of the radiation was 0.006 nm, which is comparable to the results of the small scale experiments. Similar efficiencies and power ratios were observed also. An important finding is that the long, 1.2 μs pulse from the SWAT laser can be efficiently injection locked using the shorter 500 ns pulse from the doubled dye laser.

The conclusion of these experiments is that the XeF laser can be injection locked to linewidths on the order of 0.005 nm with efficiencies on the order of 90% or better. Only modest injection source intensities are needed to accomplish this.

SWAT Raman Oscillator Experiments

Preliminary experiments with a molecular hydrogen Raman oscillator have begun. Prior to this, it was necessary to improve the optical beam quality of the SWAT lasers. This was done by using a positive branch unstable resonator. Although the laser operated with a resonator magnification of 3, the Raman oscillator experiments were performed using a magnification of 1.9. No problems with parasitic oscillations were observed.

Figure 6 shows the experimental arrangement for the Raman oscillator experiments. Radiation from the SWAT laser was focused into a 2-meter long cell containing hydrogen at a pressure of 6.3 absolute atmospheres. The laser was operated broadband

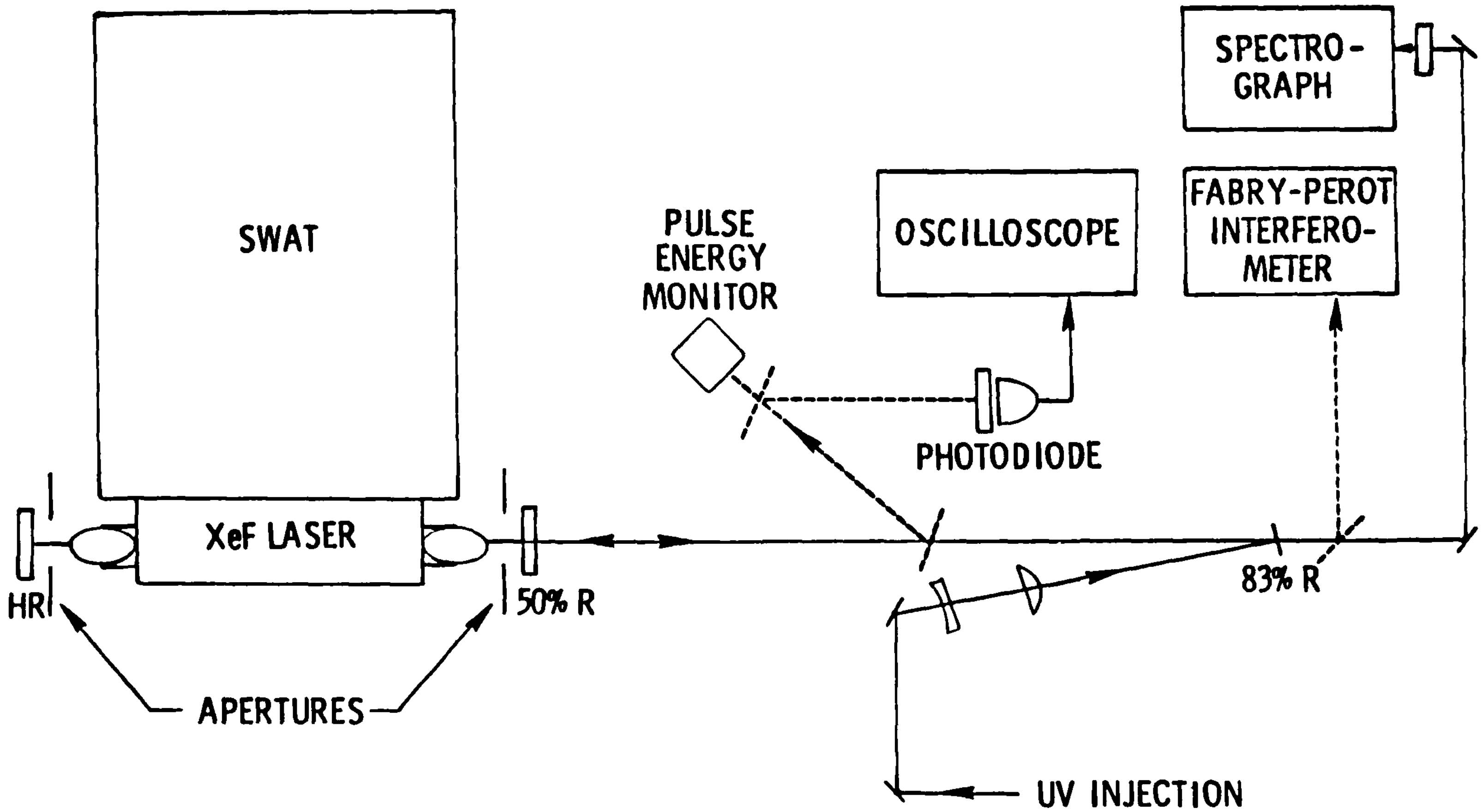


Figure 5. SWAT XeF Laser Injection Locking Experiment

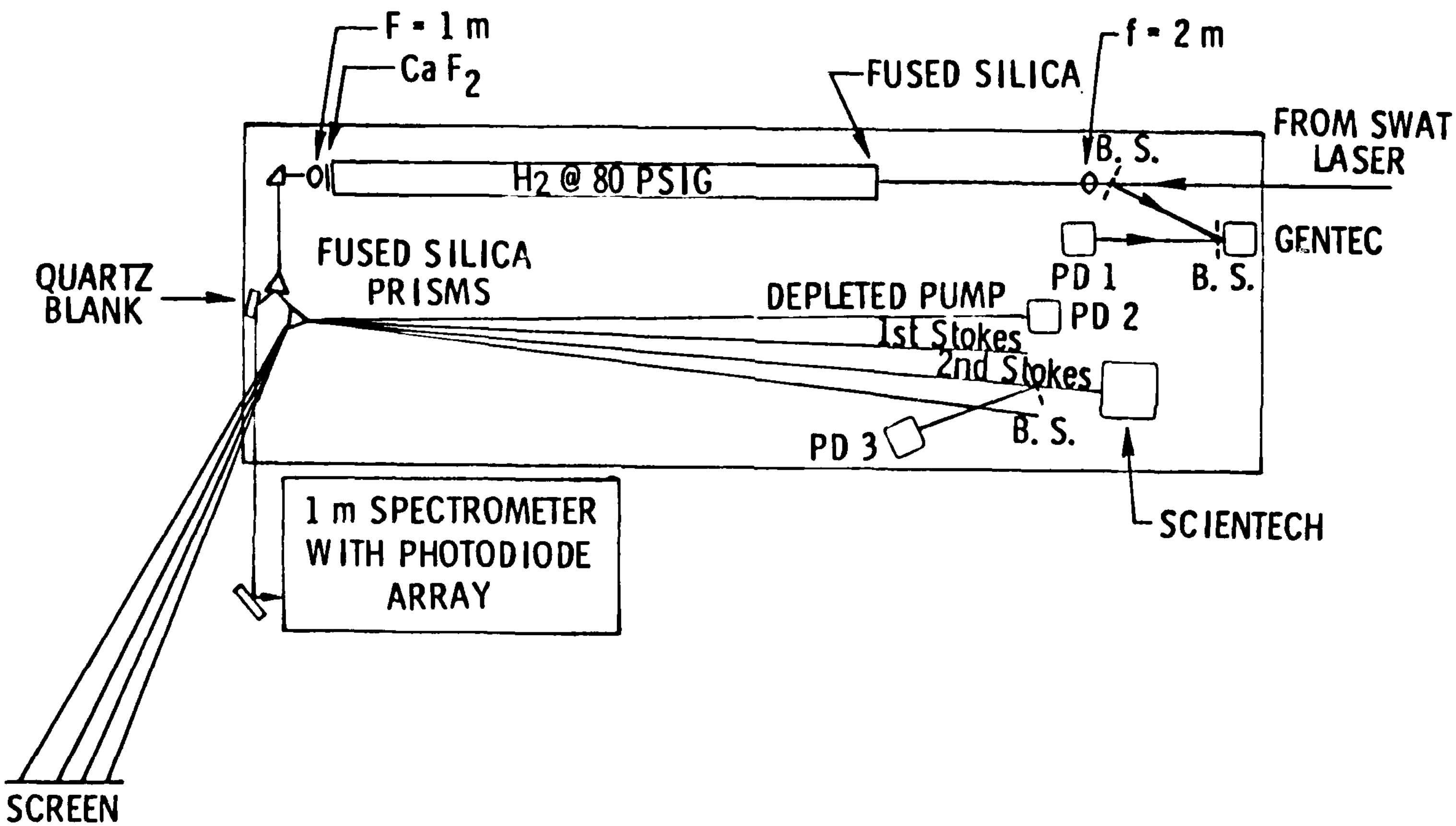


Figure 6. Setup for Raman Oscillator Experiments

(no injection locking), but a magnification 1.9 unstable resonator was used to obtain good optical beam quality. The beam exiting the cell is recollimated and dispersed with a pair of fused silica prisms. Photodiodes are used to measure the power of the input and depleted pump pulses and the second Stokes pulse. Energy meters are used to measure the pulse energy in the input pump and second Stokes pulses. Figure 7 shows typical pulse shapes in the Raman oscillator experiments. Multiple Stokes orders, up to third Stokes, are observed, with over 10% of the pump energy appearing in the second Stokes order. This is in agreement with theoretical predictions.

Future Schedule

Work on the final task under this contract has begun. Optical components for the Raman oscillator-amplifier experiments have been ordered. With the exception of several output couplers to operate the SWAT laser with a larger mode unstable resonator, all these components have been received. The Raman amplifier cells have been constructed and are being assembled in the laboratory.

Initial experiments will demonstrate efficient Raman conversion into the second Stokes order using relatively small laser volumes ($V \approx 2$ to 3 liters). Following these experiments, larger apertures will be used.

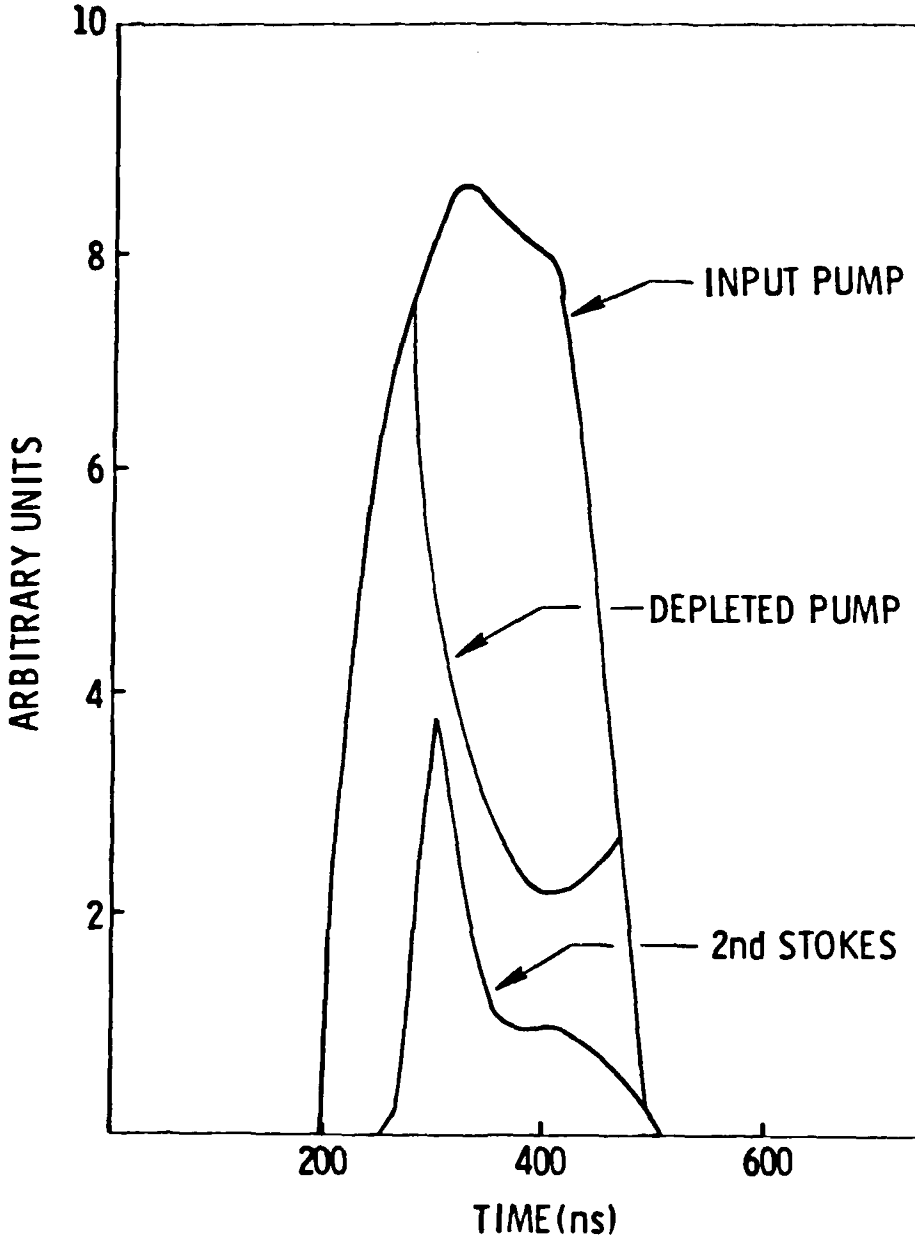


Figure 7. SWAT Laser Raman Oscillator Pulse Shapes