High Efficiency Ultraviolet Light Generation

by **D. J. Armstrong and A. V. Smith**

Motivation—Tunable, high-pulse-energy ultraviolet (UV) light is required for air- or satellite-based remote sensing missions including standoff detection of chem-bio agents, verification of nonproliferation of weapons of mass destruction, and for measuring stratospheric ozone concentration. However, designing tunable UV sources for deployment in these platforms remains a serious technical challenge, where high efficiency and reliable operation under widely varying environmental conditions are of utmost importance. Some light sources can use simple harmonic conversion alone to access the UV, with 355 nm and 266 nm being familiar examples for Nd:YAG. However non-harmonic tunable UV sources require additional nonlinear optical frequency converters such as optical parametric oscillators (OPOs). Most conventional OPO designs fail to meet specifications for conversion efficiency and durability required for airborne or satellite deployment. Recent advancements in OPO technology help address these shortcomings.

Accomplishment—Using the Sandia-patented RISTRA OPO (rotated image singly-resonant twisted rectangle) shown in Fig. 1 we have developed a Nd:YAG pumped UV generation system that is efficient, robust, and resistant to optical damage. The image-rotating RISTRA is ideal for UV generation because of its excellent beam quality. With its non-planar geometry, the RISTRA cavity requires no mirror adjustments so its mechanically stable quasi-monolithic design is ideal for remote sensing applications, as well.

Our UV generation system uses sum-frequency generation (SFG) to mix the 803 nm signal wave of the OPO with the 532 nm pump wave to generate 320 nm light. Its key features include image rotation, which works in conjunction with crystal birefringence to produce excellent beam quality; pulsed injection seeding, which reduces cavity build-up time so the 532 nm pump and 803 nm signal temporal profiles match in time; and the use of large diameter beams with flat-topped spatial profiles for optimum mixing efficiency and reduced risk of optical damage.

Our goal is high conversion efficiency in the OPO and in subsequent SFG stages. The measure of OPO efficiency is pump depletion, which quantifies conversion of pump energy to the OPO signal and idler waves. Figure 2(a) shows unusually high depletion of 88% resulting from pulsed injection seeding and the use of flat-topped beams. High-energy, high-efficiency SFG requires a large diameter flat-topped near-field spatial profile with minimal wavefront distortion, as shown in Figs. 2(b) and 2(c). The optical-to-optical efficiency of our system (1064 nm to 320 m) exceeds 20%, and its maximum UV energy is approximately 200 mJ.

Significance—High-efficiency, high-energy UV generation using stable, mechanically robust RISTRA OPOs opens the door to a variety of remote sensing applications. When combined with diode-pumped all-solid-state pump lasers, RISTRA-based UV generators can achieve high overall system efficiency in small packages that are suitable for deployment in the harsh environments of airborne- or satellite-based platforms.

Sponsors for various phases of this work include: National Aeronautics & Space Administration (NASA) Langley Research Center (LaRC), and Nuclear Weapons

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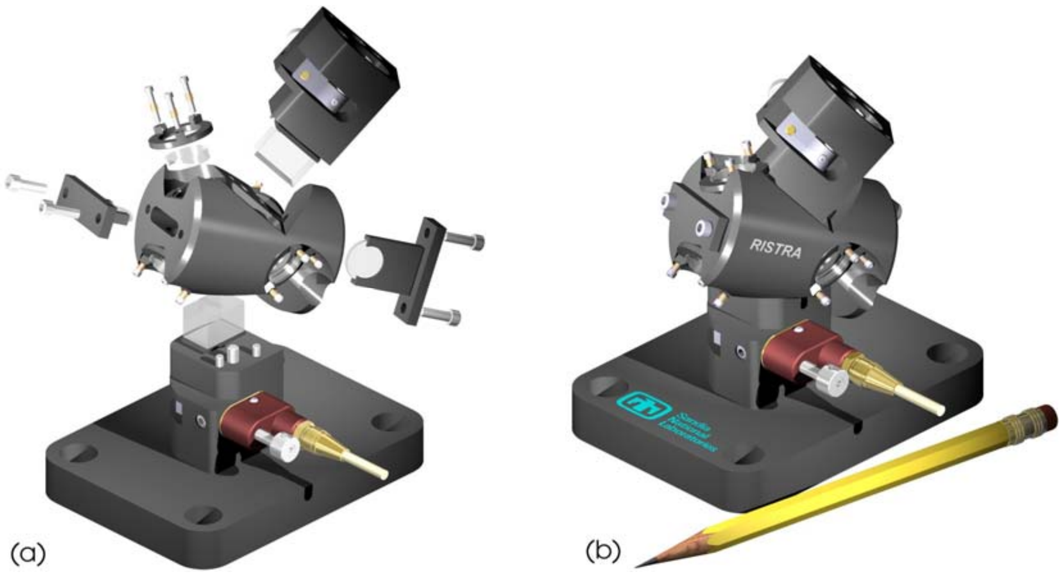

Figure 1. (a) Exploded view of a two-crystal RISTRA OPO, denoting rotated image singly-resonant twisted rectangle. Owing to its non-planar geometry cavity mirrors of the RISTRA require no tilt adjustments and are held against machined faces on the cylinder by spring-loaded retainer rings. λ/2 retardation plates insert into each end of the cylinder to control intra-cavity polarization. For UV generation the OPO is pumped by 532 nm light from an injection-seeded Nd:YAG laser, with potassium-titanyl-arsenate crystals generating an 803 nm signal and 1576 nm idler. The OPO is pulse-injection-seeded for high efficiency, and the pump and pulsed-seed beams have flat-topped spatial profiles. (b) Assembled two-crystal RISTRA OPO. The length of the cylindrical body is 1.97 in.

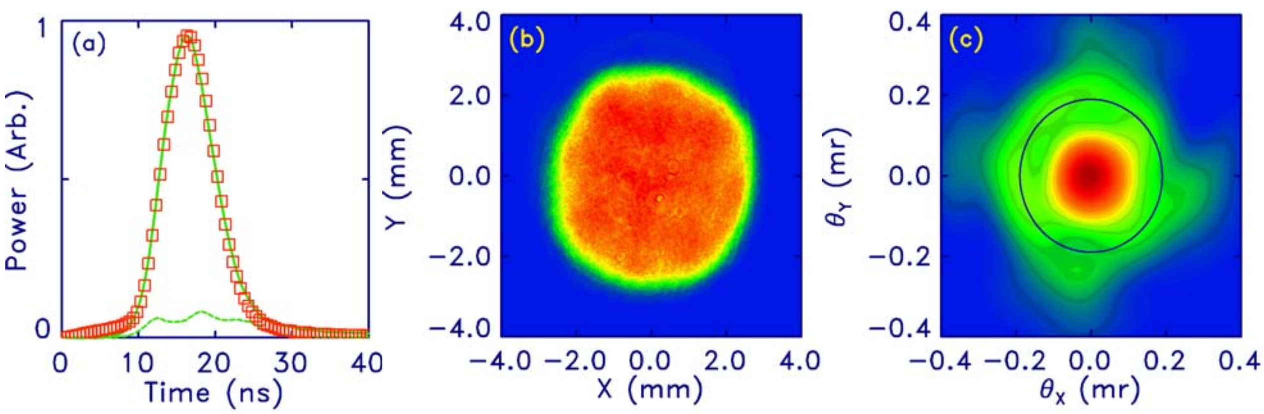

Figure 2. (a) A comparison of depleted (dashed) and undepleted (solid) pump pulses showing 88% conversion of pump energy to the signal and idler waves. Red boxes show the resulting signal pulse, normalized to the undepleted pump. Near identical pump and OPO signal temporal profiles enhance SFG efficiency through their increased temporal overlap. (b) Flat-topped near-field OPO signal spatial fluence profile, and (c) corresponding far field spatial fluence profile. The blue circle in (c) denotes the first Airy null for the near-field profile in (b) and contains approximately 60% of the energy in the far-field. Using an OPO beam having a flat-topped spatial profile and low wavefront distortion also enhances SFG efficiency.