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Fission Reactor Pumped Lasers: History and Prospects

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A. Early Work at Sandia

In late 1972 Sandia researchers began to investigate reactor pumping of lasers. Initial experiments were performed on reactor-ionized electrical excitation of the CO_2 laser.[1] In the spring of 1974 small-signal gain and lasing were observed in CO gas cooled to 77K, providing the first clear observation of lasing with pure fission-fragment excitation.[2]

Preliminary systems studies were then performed to study scaling of the laser-excitation structure to very large sizes to produce very large lasers, using current reactor technology.[3,4] An early attempt at experimental scaling of the CO laser at 77K was made with the Folded Path Laser apparatus, which lased at a power ~100 W. Lasing was also observed in rare gas mixtures and in CO gas mixtures at room temperature. Collaborative work with the University of Illinois also resulted in the first visible-wavelength reactor-pumped laser.[5]

B. Recent Work at Sandia

Recent work has utilized the Sandia Pulsed Reactor III (SPR-III) for experiments at high excitation rates with small laser volumes, and the Sandia Annular Core Research Reactor (ACRR) for experiments at lower excitation rates with larger laser volumes. Gas lasers operating in the ultraviolet and infrared wavelength regions have been studied.

On the SPR-III the energy deposition rate in the laser medium was experimentally maximized, to increase the possible range of lasers that could be studied. In the course of this work it was discovered that as little as 6 gm of enriched uranium surrounded by moderator in the central cavity of the SPR-III increased the pulsewidth by a factor of seven.[6] The maximum laser excitation rates obtained were ~10 kW/cc with ^3He excitation,[7] and ~2 kW/cc with fission fragment excitation.[8]

In connection with experiments on the XeF laser, sensitive techniques were developed at ~0.35 microns for measuring small-signal gains as low as 0.5%/pass (using a tunable probe laser), and for measuring laser cavity losses as low as 1%/roundtrip (in the hostile radiation environment of the reactor core region, and in the presence of intense fluorescence and transient gas-lensing effects from the laser medium). When XeF laser media were excited, a gain coefficient

of 0.7%/cm was observed at 0.351 microns with ^3He excitation at several atm.[8] Intermittent gains ~0.5%/cm were also observed with the tunable probe laser, for fission fragment excitation of XeF gas mixtures using Ar buffer gas at ~1 atm. However, attempts at lasing with either type of excitation at ~2 kW/cm^3 were unsuccessful.[9]

Detailed models of the entire fission-fragment laser-excitation process have been developed in collaboration with the University of Illinois, beginning with the XeF laser.[10] Measurements were also made of the refractive-index gradients (and consequent thermal lensing) induced in laser media by fission fragment excitation of laser gases at moderate to high pressures, with uranium-containing wall coatings.[11]

More recently, studies have been performed on the reactor-pumped Xe atomic laser transitions at 1.73 and 2.03 microns (first observed in reactor pumping by Russian workers[12]). Lasing has been observed with the ACRR and SPR-III reactor facilities,[9] and Rigrod experiments were performed to measure small-signal gain, saturation intensity, and nonsaturable losses. In these experiments pump power densities have ranged from 5 - 1000 W/cm^3. Small-signal gains ~0.7%/cm have been measured at 1.73 microns in Ar/Xe mixtures, with laser energy efficiencies ~3%, and power efficiencies ~5%. Small-signal gains ~1 - 3%/cm have been measured at 2.03 microns in He/Ar/Xe mixtures, with energy efficiencies ~2.4%. Non-saturable losses appear to be very small.[13] By using a combined stable/unstable resonator, ~1 J of laser energy has recently been obtained. Lasing has also been observed at ~2 microns in He/Ar using the ACRR facility.

C. Prospects for Reactor-Pumped Laser Work at Sandia

Current work involves several areas: Measurements of kinetic parameters of lasers (such as collisional quenching rates from laser levels), measurements of laser efficiency as a function of energy and power loading in the laser gas, model development by collaborators at the University of Illinois, experiments on extraction of laser energy from a larger portion of the excited region through the use of unstable laser resonators, and development of specialized equipment for excitation of larger volumes of laser gas, such as the Advanced Laser Excitation Cavity ("ALEC") at the Sandia ACRR Facility. Adaptive optic concepts to correct for refractive-index gradients during the longer excitation pulses of the pulsed-TRIGA type reactor (such as the Sandia ACRR) are also being developed.[14]

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