Extending from diode-pumped alkali vapor lasers (DPAL), Han and Heaven have shown that rare gas metastable states, np^2(n + 1)s[3/2]m, can operate as the base of a three-level laser with excitation of the (n + 1)s → (n + 1)p transitions. Though both the rare gas lasers (RGL) and DPALs can be excited with incoherent optical pumping, RGLs do not suffer from the highly reactive behavior of alkali metals. Since metastable populations are maintained via electric discharge, we propose using a tuned electron energy distribution function (EEDF) to modify RGL efficiencies and drive the population inversion. The EEDF is maintained by the discharge along with the introduction of electron sources. Using our kinetic global modeling framework (KGMI) and two gas systems (helium buffered argon and pure argon), we first validate the intracavity intensity laser model and then generate gain and energy efficiency baselines for each system. Parameter scanning methods are then used to find optimized EEDFs and system parameters for metastable production, generation of a lasing population inversion, and increasing RGL operation efficiencies. Finally, we determine if an RGL can operate without optical pumping.

**DPAL → RGL**

DPAL, first published by Krupke et al. [1], demonstrating three-level laser oscillation between the metastable states, can operate as the base of a three-level laser with excitation of the metastable states. Han and Heaven [2] showed transitions between the noble gas excitations, np^2(n + 1)s[3/2]m, and dp^2, dp^3, and dp^5 excited levels of Rb and Cs.

Simplified systems • Neutral collision partners • Lower temperature • Inert reagents in system

Not directly possible: • Inert reagents in system • Low temperature • Neutral collision partners

Both systems are attractive due to the coherent nature of the output.

**Future Work**

• Tracking a discretized spectral distribution
• Indirect methods for plasma pumped laser
• Continuing He buffer study with Kr

**References**


**Optically-Pumped Argon Laser Models**

Recreating the experimental results of Han and Heaven

• Optical pumping: centered at 811.75nm, Δν = 30GHz, 10μs duration, and energy of 0.25mJ
• Gas cell: R = 2.5cm, L=60cm over a range of pressures
• RF power: 18kV separated by 2.5 cm for 10ns
• Observed optimized delay between discharge and laser pulses 5-25μs

**Pure Plasma Laser Concept**

Equilibrated argon species responding to MW discharge followed by optical pumping pulse.

**Argon with Helium Buffer**

Difficulty in exciting He yields a good buffer gas

• He species considered: He and Hel
• Non-linear relationship between He:Ar ratio and output intensity

Optimum He:Ar ratios and pulse delay times can be found for each background pressure.

**Kinetic Global Modeling**

General species continuity and electron energy equation (solved for T_e) with reaction rates K_i

\[ \frac{d n_i}{dt} = \sum_i \beta_i K_i \Pi n_i - D_{ii} \]  

\[ \frac{d}{dt} \left[ \frac{3}{2} n_i T_e \right] = P_{\Pi} - \sum_i n_i K_i \Delta E_{ij} \]

Integrated reaction rates (when cross section is known, e.g. [3]) with parameterized EEDFs

\[ K_i(x, T_e) = \int_0^\infty d\epsilon \epsilon \sigma_i(\epsilon) f_\epsilon(x, \epsilon, T_e) \]

MW power deposition: assumed power absorption or time-enveloped effective electric field convolved with EEDF

**Laser Model: Pumping and Output**

Two-way averaged plane-wave model with assumptions on spectral distribution [3]

\[ \beta_{ij} = \frac{\sigma_{ij} n_j}{g_j} \]

Pumping intensity derived independent of the ν distribution

\[ \Omega(t) = \frac{\beta_\Pi}{l_\Pi} l_\Pi (1 - \exp[\beta_\Pi]) (1 + \int_0^\infty R \epsilon \exp[\beta_\Pi]) \]

The output intensity is defined from the two-way intracavity circulating intensity, with continuity equation

\[ \frac{d\Psi}{dt} = (t_\Pi R \exp[2\beta_\Pi] - 1) \frac{\Psi}{\tau_\Pi} + n_i \frac{\sigma_{ij} c^2 \nu_{ij}}{l_\Pi} \]

Which is related to the output intensity as

\[ I_{out}(t) = \eta \Psi(t) \]

Note: R is the power reflectivity and t are the pump and laser gain cell window transmission coefficients

**Optima discharge time between discharge and optical pump:**

Optimum delay time between discharge and optical pump: [Ar] = 4.25m\(^2\)/s → 2.3 μs

**Optima discharge instead of RF:**

20ns gaussian discharge and output power: 1.2mW