

Collisional-radiative calculations for the $3p^1S_0 \rightarrow 3s^3P_1$ lasing line of neonlike germanium under anisotropic collision conditions

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Synopsis Rate coefficients for collisional transitions between magnetic M -sublevels of 75 levels in neonlike germanium ions are calculated for both Maxwellian isotropic electron velocity distribution and monoenergetic electron beam. These are used in a steady-state collisional-radiative model to obtain differences between the $\Delta M = 0$ and $\Delta M = \pm 1$ gain components of the 19.6 nm $3p^1S_0 \rightarrow 3s^3P_1$ lasing line under anisotropic collision conditions in the amplifying plasma.

Most existing gain calculations for soft x-ray lasers pumped by electron collisions in laser-produced plasmas assume a Maxwellian isotropic electron velocity distribution. Fast electrons with a strongly anisotropic angular distribution could be present in plasmas when solid targets are irradiated by high-intensity ultrashort-duration laser pulses [1]. Such electrons can lead to different populations of magnetic M -sublevels after collisions with ions, affecting the polarization properties of laser lines.

In the present work, we examine differences between the $M = 0 \rightarrow M' = 0$ ($\Delta M = 0$) and $M = 0 \rightarrow M' = \pm 1$ ($\Delta M = \pm 1$) gain components of the 19.6 nm $3p^1S_0 \rightarrow 3s^3P_1$ lasing line of neonlike germanium under cylindrical symmetry conditions of the electron velocity distribution. We consider a velocity distribution model that includes both Maxwellian isotropic and monoenergetic beam electrons [2, 3]. We focus on the emission of the lasing line at the beginning of the plasma column far below saturation, where stimulated emissions can be disregarded. We use a steady-state collisional-radiative model to determine the populations of the upper $M = 0$ and lower $M' = 0, \pm 1$ sublevels of the lasing line as a function of electron density in the $10^{19} - 10^{22} \text{ cm}^{-3}$ range. This model includes collisional excitation and de-excitation, and spontaneous radiative decay among the 337 M -sublevels that arise from the 11 configurations $2p^6$, $2p^53l$, $2s2p^63l$ ($l = 0 - 2$) and $2p^54l$ ($l = 0 - 3$). The calculations were performed for various temperatures T_e of the Maxwellian component in the range 100 – 700 eV and kinetic energies e_0 of the beam component from 1.5 to 20 keV at a beam fraction of 5%.

All basic atomic parameters needed for the calculations, including energy levels, spontaneous emission probabilities and collision

strengths, were calculated with the flexible atomic code (FAC) [4]. However, some approximations were introduced to get the 4π -averaged collision strengths for optically allowed and forbidden transitions between M -sublevels belonging to levels with non-zero angular momenta, which cannot be provided by FAC. Those collision strengths are required to evaluate the Maxwellian-averaged rate coefficients. Other approximations used enabled us to have access to collision strengths for deexcitations by beam electrons as well, which also cannot be given by FAC.

Table 1 shows a typical example of the Maxwellian-averaged and beam rate coefficients for the transitions $3s^3P_1 M_i = 0, 1 \rightarrow 3p^1D_2 M_j = 0 - 2$, which are among the strongest ones.

Table 1. Maxwellian and beam rate coefficients ($10^{-10} \text{ cm}^3 \text{ s}^{-1}$) for the $3s^3P_1 M_i \rightarrow 3p^1D_2 M_j$ excitations at various values of T_e and e_0 , respectively.

$M_i \rightarrow M_j$	T_e (eV)			e_0 (keV)	
	200	400	700	2	10
$0 \rightarrow 0$	10.9	9.57	8.32	4.15	1.57
$0 \rightarrow 1$	8.19	7.18	6.24	5.27	3.67
$1 \rightarrow 0$	2.73	2.39	2.08	1.76	1.22
$1 \rightarrow 1$	8.19	7.18	6.24	3.12	1.18
$1 \rightarrow 2$	16.4	14.4	12.5	10.5	7.33

A maximum ratio of the $\Delta M = 0$ and $\Delta M = \pm 1$ gain components of the lasing line was found to be near 1.1 at $T_e = 100 \text{ eV}$ and $e_0 = 4 \text{ keV}$.

References

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