The Kinetic Effects of HBr Partial Pressure and Gas-Flow Rate in Cu HyBrID Lasers

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In Cu 'HyBrID' lasers (also referred to as Cu-Ne-HBr lasers), the lasant Cu atoms are generated *in situ* as byproducts of discharge and surface reactions involving solid Cu pieces placed in the tube bore and a controlled amount of HBr gas additive. Though the principal role of the HBr additive is to generate free Cu, the HBr additive also has important positive effects on the plasma kinetics. Cu HyBrID lasers have yielded several fold increases in laser efficiency (>3%), high beam quality output power (>100 W) and optimal operating pulse rate (>17 kHz) compared to conventional copper vapour lasers. These enhancements are primarily attributed to the acceleration of charge neutralisation during the interpulse period via the large HBr cross-section for dissociative electron attachment.

Laser performance depends critically on the partial pressure of HBr added to the Ne buffer-gas and the buffer gas flow rate of the mixture. Maximum laser output has been obtained when using HBr partial pressures typically 1-5 mb at gas flow rates approximately 1-5 $atm.l.hr^{-1}$. Non-zero flow rates of the mixture are essential for sustaining laser output in order to compensate for the condensation loss of reactive Br species in the cold end-regions[1]. To date, however, the factors which determine the optimal buffer gas conditions are not well understood. In particular, the effects of HBr partial pressure and buffer gas flow rate on the free Cu density and rate of interpulse plasma relaxation have not been studied in detail Understanding these factors is important for developing strategies to optimise the operating buffer gas conditions when scaling laser output power and pulse rate.

In this study, we have investigated the effects of HBr partial pressure and buffer-gas flow rate on the kinetics by measuring their effects on the time behaviour of the Cu ground-state ($Cu\,^2S_{1/2}$) density. $Cu\,^2S_{1/2}$ density measurements present a powerful method for investigating the key kinetic effects of gas flow since the prepulse $Cu\,^2S_{1/2}$ density is essentially equal to the free Cu density in the plasma, and the rate of $Cu\,^2S_{1/2}$ density regrowth is representative of the interpulse rate of Cu^+ neutralisation and quenching of Cu* atoms.

It is found that the recovery rate of $Cu\,^2S_{1/2}$ density during the interpulse period increases linearly with HBr partial pressure when varying either the HBr or Ne mass flow rate. However, the free Cu density in the plasma only increases notably when increasing the HBr mass flow rate. We explain this behaviour using a simple model for the major production and loss fluxes of the species in the plasma which participate in the key Cu surface and kinetic reactions in the plasma tube. Within this model the ambient densities of Br species and free Cu are determined by the balance of the number of HBr molecules entering the tube with the gas flow (ie. the HBr mass flow rate) and diffusion loss to the cold end-regions where they are removed from the gas phase by CuBr condensation. The ambient densities of H species (eg. H, H_2 and HBr) on the other hand, which are expected to significantly impact the rate of interpulse plasma relaxation, mirrors the added HBr partial pressure. The implications for optimising buffer-gas conditions when scaling laser output power and the development of sealed-off Cu lasers will be discussed

[1] R P Mildren and J A Piper, paper CThH14, *ECLEO* '98, Glasgow

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