Detailed plasma source modeling for hydrogen masers

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In a hydrogen maser atomic clock [1], a beam of state selected hydrogen atoms is sent towards a storage bulb located at the center of a cylindrical electromagnetic cavity to induce stimulated emission processes at 1420.406 MHz between the hyperfine levels $F = 1$ and $F = 0$ of the $1s_{1/2}$ hydrogen ground state. The hydrogen atoms are obtained through molecular dissociation in a standard radiofrequency (RF) discharge bulb. The RF electromagnetic wave sustains a plasma (see Fig. 1 inset) where many atomic and molecular processes take place and compete, among which molecular dissociation. The experimental parameters (mainly the bulb geometry, RF injected power, molecular gas pressure in the bulb, and bulb inner surface composition) are properly selected to optimize atomic hydrogen formation.

Here, we shall present a comprehensive global plasma modeling (see Fig. 1) with a set of as many as 17 possible chemical reactions inside the plasma volume, 8 atomic and molecular hydrogen excitation processes and 4 surface reactions. The plasma particle densities for atomic and molecular hydrogen, as well as for all possible hydrogen ionic species (i.e., H^+, H_2^+, H_3^+ and H^-), are predicted as a function of all experimental parameters. The specific role of the ion species H_3^+ and H^- will be discussed. We shall show that lower pressure regimes in comparison with what is usually considered for ground and spatial hydrogen maser atomic clock operation should preferably be considered for optimal atomic hydrogen production.

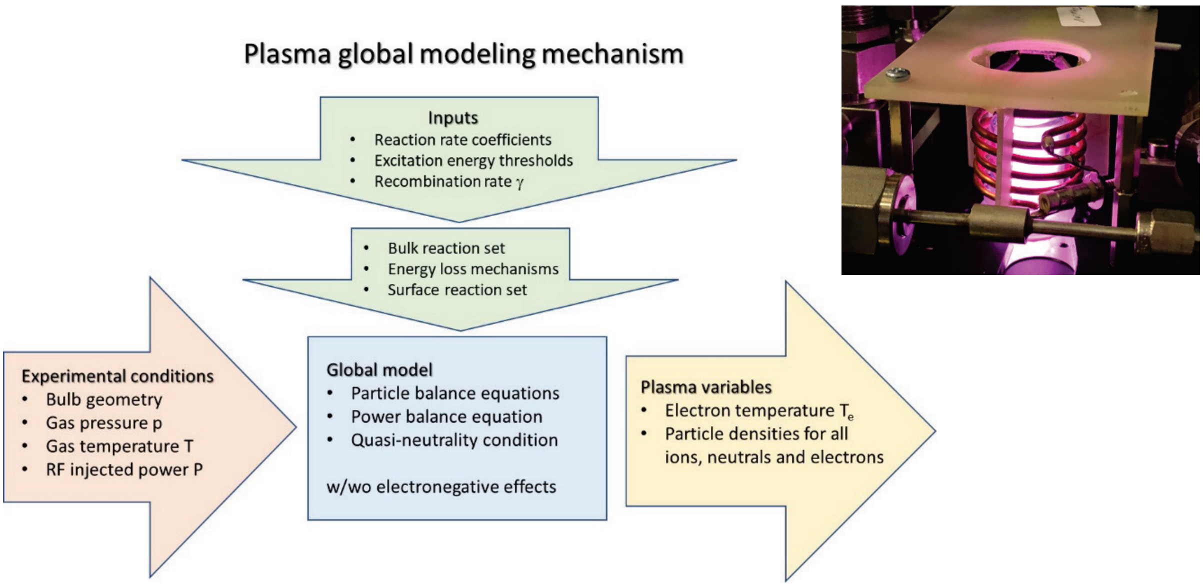

Fig. 1: Principle of a global plasma modeling (inset: hydrogen discharge bulb and its plasma).

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