분과초청 5

XHV Measurement by Laser Ionization

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The ionization of atoms and molecules by laser is so efficient that the detection of a single particle is possible, and it has been applied recently to pressure measurement in ultrahigh vacuum (UHV) region and extreme ultrahigh (XHV) region.

The density of residual gas molecules (mainly H_2, Co and Co_2) is very low, e.g., only a few molecules/mm^3 in 10^{-11} Pa region. And the ionization probability strongly depends on the incident laser power density when nonresonant multiphoton ionization (NRMPI) is used. Therfore, not only the ionization of residual molecules at high probability but the accurate estimation of the ionization region are necessary for XHV measurement by the laser ionization. In the present study, current state and problems of XHV measurement by the laser ionization is presented.

A picosecond YAG laser (pulse width: about 30 ps) was used for the ionization of H_2 and Xe. They are ionized by 7-photon process (H_2) and 6-phonon process (Xe), respectively, with second harmonics of the YAG laser. Saturation of the NRMPI of H_2 was observed at the incident laser energy above 15 mJ/pulse, which corresponds to the focused power density above $\sim 10^{13}$ W/cm^2. Under such condition of the incident laser beam, the proportional relationship between the laser generated ions and the H_2 gas pressure in an XHV chamber was verified to the order of 10^{-10} Pa, i.e., the detection limit of a commercial vacuum gage. It was also verified that the laser ionization technique has enough pressure sensitivity in 10^{-11} Pa region, too. Then, the region of laser ionization was directly measured with a new detection system which is consisted of a static lens, microchannel plate (MCP) intensifier, a CCD(charge coupled device) camera, and an image processor. Ions generateted by each laser pulse were detected as bright spots on the MCP intensifier, and appeared along a laser beam path. The ionization region had a spindle shape with the maxium diameter at the focal point of the incident laser beam. The size of the ionization region was also estimated to be about 0.05 mm at the maximum diameter and about 2.5 mm in length.