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ヘリウム原子近赤外分光法のダイバータ模擬装置MAP-IIへの適用

Near-Infrared Spectroscopy for Atomic Helium Lines for MAP-II Divertor Simulator

門信一郎, 飯田洋平*, 山野守史, 渡邉智史, 阿部翔太**
KADO Shinichiro, IIDA Yohei*, YAMANO Morifumi, WATANABE Satoshi, ABE Shota**
東大院工 (現所属： *筑波大, **米UCSD)
Univ. Tokyo (present affiliations: *Univ. Tsukuba, **UCSD, USA)

Intensity ratio of atomic helium line (He I) has widely been used to evaluate the electron density and temperature in fusion-relevant divertor and in divertor-simulating plasma facilities. This method employs a collisional radiative model to determine the quasi-steady state solution of the rate balance equations in terms of population density of the excited states. In addition to the excitation, ionization, recombination or spontaneous emission processes, radiation trapping – also referred to as reabsorption, self-absorption, radiative transfer, or radiation transport – has been pointed out to play a crucial role in low-temperature (namely low-degree of ionization) plasmas [1]. In particular, the radiation trapping between ground and 2^1P states causes the strongest effect on the population distribution through redistribution to the other states [2]. Even though, direct determination of the 2^1P states population is difficult because the emission to the ground state has the wavelength of 58.4 nm in the vacuum ultraviolet (VUV) regime. Moreover, such resonant transitions with ground state are optically thick due to the high ground state density, so that the interpretation of the measured spatial distribution of the line intensity may need careful consideration.

In this study, we have developed a near-infrared (NIR) spectrometer system to measure 2^1S - 2^1P optically thin radiative transition of 2058.130 nm to evaluate the spatial distribution of the 2^1P state (see Fig. 1). A merit in this approach is that the visible spectroscopic technique can apply with some modification.

We modified a Czerny-Turner spectrometer (SOLAR TII inc., MS3504i) 35 cm in focal length, 3.8 in F-number. The grating with the groove frequency of 300 G/mm allows access to NIR spectral regime. The "flat-field" of the spectrometer is 28 x 10 mm^2 in dimension where a two-stage thermoelectrically cooled (~ -20 ºC) InGaAs linear imaging sensor (Hamamatsu G9208-256W, 0.03(H) x 0.25(V) mm^2 in pixel size, 256 ch, 0.05 mm in horizontal pitch between pixels) is installed. The sensitive wavelength region is 900 - 2550 nm covering the 2^3S - 2^3P (1083 nm) line as well. Furthermore, the detector has some sensitivity in visible region, so that the strong visible lines and their higher order diffraction can be used to calibrate the wavelength and the reciprocal linear dispersion, which has been determined to be 9.3 nm/mm around 2058.130 nm.

By applying the pure helium discharge in MAP-II divertor simulator [3], remarkable broadening in the spatial profile of the 2^1P state was observed, suggesting significant contribution of the radiation trapping. This result is useful in evaluating the spatial distribution of radiation trapping [4] and including it in the self-consistent collisional radiative model calculation.

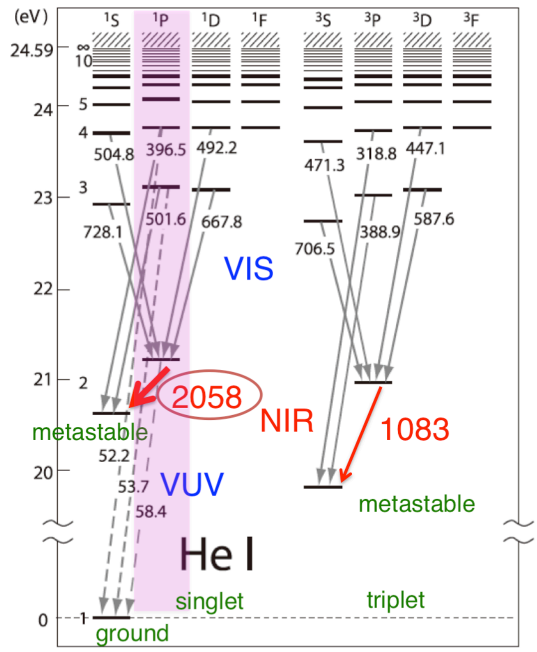

Fig. 1 Grotrian diagram of atomic helium line spectra (He I) with transition wavelength in nm.

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[4] Y. Iida, S. Kado, S. Tanaka, Phys. Plasmas **17**, 123301 (2010).