Application of Monte Carlo Code to Large Mirror Device - Upgrade

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(Received November 28, 2007)

Abstract

Monte Carlo code developed in RIAM, Kyushu University, is applied to Large Mirror Device - Upgrade. Comparison of calculated neutral pressure with measured one demonstrates good agreement without the plasma. In the case of plasma discharge, unknown parameters such as the ion temperature and the speed of plasma flow are shown to be estimated. To improve accuracy of the estimation, position of the manometer is recommended to shift away from the end plate and the idea to use two manometers in combination with simulation is proposed.

Key words : *Monte Carlo, neutral transport, simulation, comparison with experiment*

1. Introduction

Nonlinear two-dimensional code calculating steady state neutral density in a linear device was developed [1]. The code uses Monte Carlo algorithm and takes experimental data as input parameters. Original version of it was applied to a case of Large Mirror Device - Upgrade (LMD-U) installed in Kyushu University [2, 3].

Recently, the code was upgraded to take into account realistic experimental plasma density profiles and also to handle neutral heating during a discharge. At the same time, three ionization gauges were installed on the device. The gauges are able to measure the neutral pressure without the plasma only. During a discharge, a manometer located close to the end plate can be used for measurements. Schematic view of the LMD-U and positions of the gauges and the manometer are shown in Fig. 1.

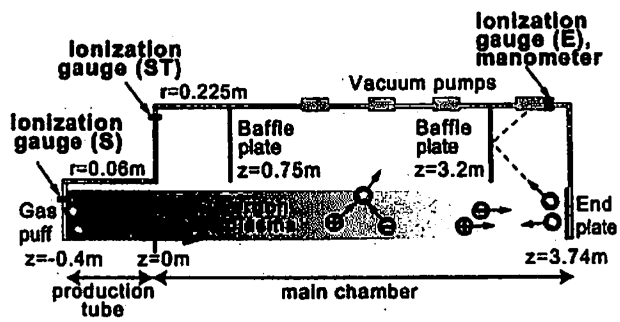

Fig. 1 Scheme of simulated device.

2. Results of simulation

With the upgrade of the code and installation of new diagnostics, direct comparison of the model calculations and experimental measurements became possible and here results are presented (Fig. 2). Three cases of the neutral filling pressure are considered: argon pressure of 1 mTorr, 2 mTorr and 3 mTorr. To make possible measurements by the ionization gauges, plasma is not generated. The results prove that calculated neutral pressure is in a good agreement with the experimental data.

During a discharge, the neutral pressure depends on plasma parameters. Previous calculations had demonstrated that neutral pressure is very sensitive to the electron density and the electron temperature [1], those quantities can be measured and present simulations are performed based on experimental data. Other plasma parameters such as ion temperature (T_i) and speed of plasma flow are difficult to measure and only ranges of expected parameters are known at a moment. Nevertheless, combination of the manometer data with the Monte Carlo code can provide additional information

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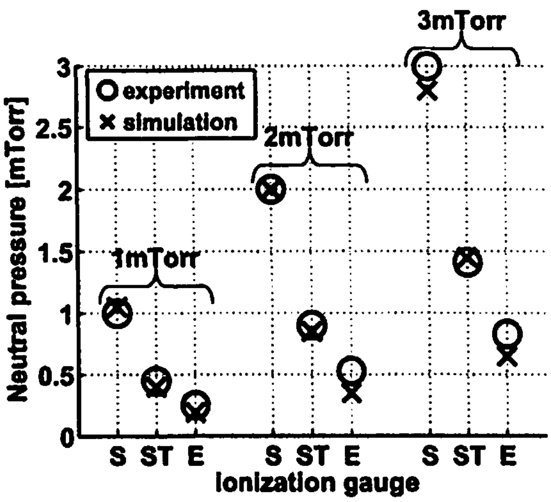

Fig. 2 Comparison of the results of simulation with measurements by the ionization gauges. The neutral gas filling pressure of 1 mTorr, 2 mTorr and 3 mTorr are considered. Positions of the ionization gauges S, ST and E are shown in Fig. 1.

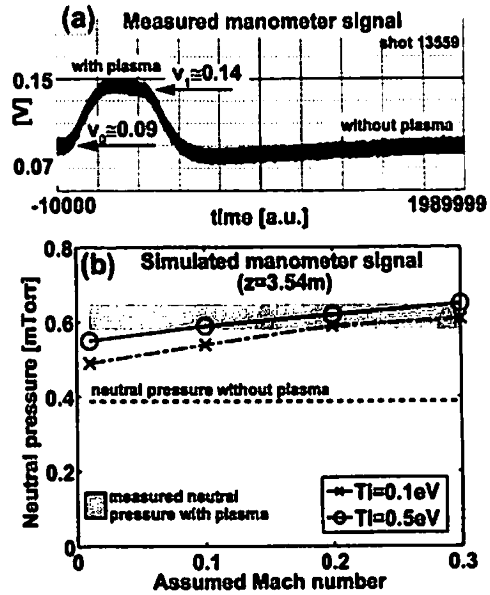

Fig. 3 Simulated manometer signal. The manometer is located at $z \approx 3.5$ m. Grey region indicates experimental results. Here, neutral filling pressure is 2 mTorr; the electron temperature is 3 eV, and multiple pumps of 100, 100, 100, 800 liter/s at $z = 1.35$, 2.3, 2.9, 3.5 m, respectively, are used; the manometer is placed at $z \approx 3.5$ m.

about T_i and speed of plasma flow. For example, experiment shows that the neutral pressure is enhanced by 1.5 – 1.7 times during a discharge as shown in Fig. 3(a). Corresponding calculated neutral pressure for expected ranges of T_i and Mach numbers (M) are given in Fig. 3(b). The shown lines can help to estimate Mach number based on measured T_i and vise versa. Note that results of simulation are in a good agreement with experiment. On the other hand, the results also demonstrate that the neutral pressure weakly depends on ion temperature and Mach number, reducing accuracy of estimation. For example, Mach number lies within $0.1 - 0.3$ if $T_i = 0.5$ eV, and if $T_i = 0.1$ eV, then $M > 0.18$.

The end plate is known to be a source of neutrals due to recombination process. High neutral pressure is unfavorable for LMD-U experiments [4], and to reduce neutral flow from the end plate to a main plasma region, an baffle plate along with a fast pump are installed close to the end plate. For this reason, neutral pressure at the manometer position ($z \approx 3.5$ m) is mostly determined by the fast pump but not by speed of plasma flow. Away form the end plate this pump does not affect the neutral pressure, and effects of T_i and M on the neutral pressure become more pronounced (Fig. 4(a)). For example at the middle point of the device ($z = 1.87$ m), dependence of the neutral pressure on Mach numbers (Fig. 4(b)) is steeper by 3 times approximately in comparison with that shown in Fig. 3. Therefore, corresponding uncertainty becomes smaller. Thus shift of the manometer position toward the production tube, improves sensitivity of the manometer signal to plasma parameters. Combination of manometer data with the Monte Carlo code will increase reliability of T_i and M measurements.

The use of two manometers can farther improve the accuracy of estimation of plasma parameters, since the neutral pressure profile nonlinearly depends on plasma parameters. Nevertheless, intensive simulations are necessary to clear this question.

3. Conclusions

The direct comparison between experiment and simulation performed in the case without plasma demonstrate a good agreement (Fig. 2).

In the case with plasma, the code needs the information for ion and electron temperatures, and plasma flow as input parameters. At present, no measurements for ion temperature and plasma flow are available. Therefore, parameter dependence of ion temperature and of plasma flow on the neutral pressure is investigated. It is found that

- the value obtained by simulation is consistent with experimental results;
- the neutral profile weakly depends on these parameters (Fig. 3(b));

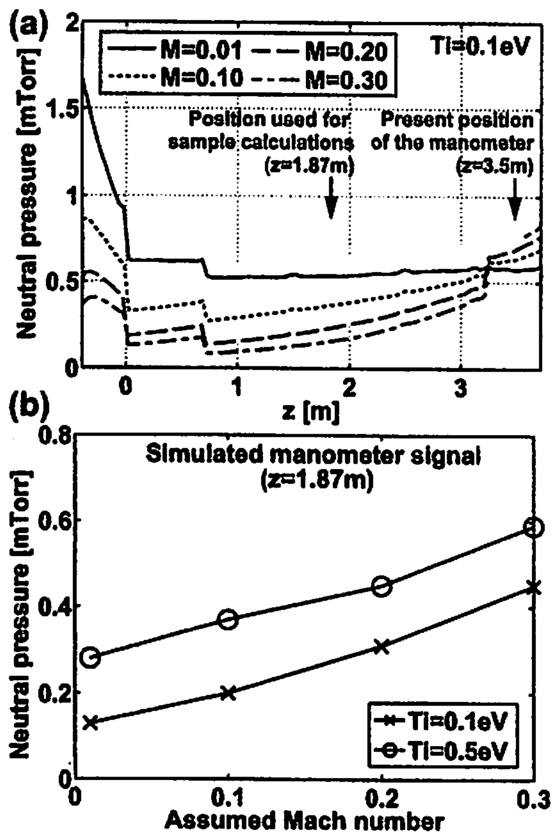

Fig. 4 (a) Radially averaged neutral pressure and (b) dependence of radially averaged neutral pressure on the ion temperature and the speed of plasma flow at the middle point of the device. Conditions of simulations are the same as in Fig. 3

- the idea to use two manometers in combination with simulation is proposed.

Based on the two dimensional neutral profile predicted by the code, the suitable manometer position in the central region of plasma where the neutral profile strongly depends on the Mach number is predicted. Calculated dependence of Mach number on neutral pressure on this location is shown (Fig. 4(b)).

4. Acknowledgment

We would like to thank Prof. Y. Kawai, Dr. A. Fujisawa, Dr. S. Inagaki, Dr. Y. Nagashima, Dr. T. Yamada, Mr. K. Terasaka, Mr. M. Kawaguchi, Mr. T. Maruta in performing the experiment.

This work is partly supported by a Grant-in-Aid for Specially Promoted Research from Ministry of Education, Culture, Sports, Science and Technology (16002005).

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ISSN 1345-5664

Reports of Research Institute for Applied Mechanics Kyushu University

九州大学応用力学研究所所報

No. 134
March 2008

Published by
Research Institute for Applied Mechanics
Kyushu University, Fukuoka, Japan