

# High-pressure Low-power Microwave Discharge using Annular Slot Antenna at the top of the Coaxial Tube

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*The high-pressure microwave discharge produced by low-power microwave has been investigated in order to apply to the high efficiency, long life light source. It is found that the discharge could be sustained by the microwave power of 10 to 30 W even at 1 atmosphere of argon and xenon gases when an annular slot antenna with 1 mm gap is used as a launcher. When NaI and ScI<sub>3</sub> are added into the discharge lamp, the lamp efficiency increased to 40 lm/W due to the visible light emission from Na atoms and Sc atoms.*

## 1. Introduction

The electrodeless mercury-free discharge lamps have attracted an increasing interest in the field of lamp industry since they are expected to achieve a long-life and high-efficiency lamps. Recently, the novel high intensity discharge lamps such as a sulfur lamp [1] and a cluster lamp [2] have been developed using microwave power higher than 200 W. Among several types of discharges using the electromagnetic wave, the surface wave discharge has such advantages that it can produce high-density plasma for wide range of filling pressure by applying electromagnetic wave through a variety of launchers. However it has a serious problem to be solved that the electromagnetic wave leaks from the discharge lamp because the main region of the surface wave plasma production is under the lamp wall and the intense electromagnetic field accumulates near the lamp wall. These are the reasons why the research aimed at lamp application has not been made until now.

In the present work, the high-pressure microwave surface wave discharge is examined using a low-power microwave of 2.45 GHz to apply to the small size discharge lamp. A part of the problems can be solved when an annular slot antenna at the top of the coaxial tube is used as the launcher and NaI-ScI<sub>3</sub> is included as the additives in the lamp filled with xenon or

argon at the high-pressure.

## 2. Experimental Apparatus

The schematic diagram of the experimental apparatus is shown in Fig.1. The attenuator is simply inserted to decrease the microwave power from the magnetron oscillator lower than 50 W. Three sorts of the slot antennas depicted in Fig.2 are used to examine the microwave leakage and the discharge behaviors. The discharge lamp is placed on the slot antenna through the quartz spacer which is inserted to keep the slot antenna gap and to suppress the breakdown of the atmosphere. The lamp wall temperature was measured near the top of the lamp by the thermocouple. The spectral distribution of the light emission from the discharge lamp was measured by the spectroscope (Ocean Optics, Inc. S2000).

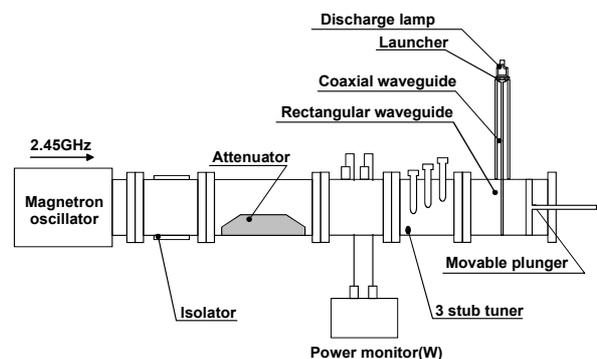


Fig.1 Schematic diagram of the experiment

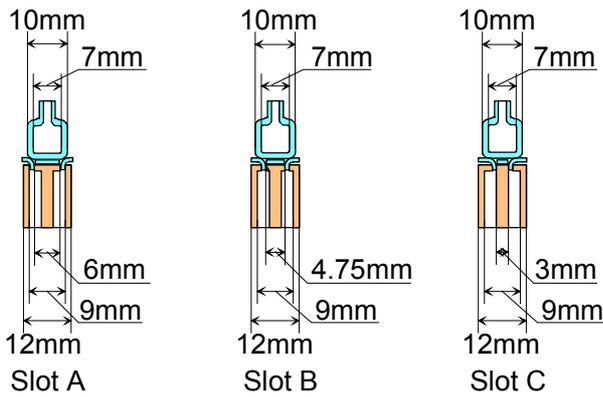


Fig.2 Slot antennas at the top of the coaxial cable

### 3. Experimental Results and Discussion

The discharge could be carried out at the argon pressure of 1 atmosphere by the continuous microwave power of 10 - 30 W. Figures 3 shows the typical discharge modes observed by slot B for the microwave power of 10 W. Figure 4 shows the microwave leakage measured at the position of 6 cm from the lamp wall. It is found that it is lower than 2 mW/cm<sup>2</sup>, which is considered the dangerous level of microwave radiation to human body.

Next, the lamp filled with argon, NaI and ScI<sub>3</sub> are examined to know the possibility of practical application to the high intensity discharge lamp. Figure 5 shows the spectrum distribution of the light emitted from the lamp in which NaI of 0.45 mg and ScI<sub>3</sub> of 0.45 mg are added in the argon gas of 300 Torr. The lamp efficiency measured by the illuminometer (Topcon, IM-3) was 40 lm/W for the microwave power of 20 W. Many spectral lines are observed in the visible region as shown in Fig.5. These are emitted from vaporized Sc and Na atoms so that the additives can significantly improve the lamp efficiency. In order to realize the lamp efficiency higher than 100 lm/W for practical use, the partial pressure of Sc should be increased by heating up the lamp wall to 1,000 °C, though the total pressure in the lamp increases to 2.45 atmosphere, which is much higher than 1 atmosphere for the measured wall temperature around 500 °C in the present experiment.

In conclusion, the atmospheric pressure discharge could be sustained in the small lamp by such a low-power microwave as 10 – 30 W, accompanied by low microwave leakage when the annular slot antenna is used. Therefore, this discharge is promising to apply the high-pressure intense discharge lamp by low- power electromagnetic wave.

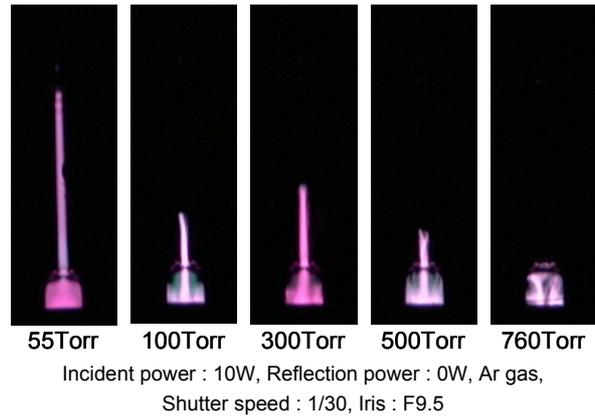


Fig.3 Discharge modes for slot B as a function of the argon pressure.

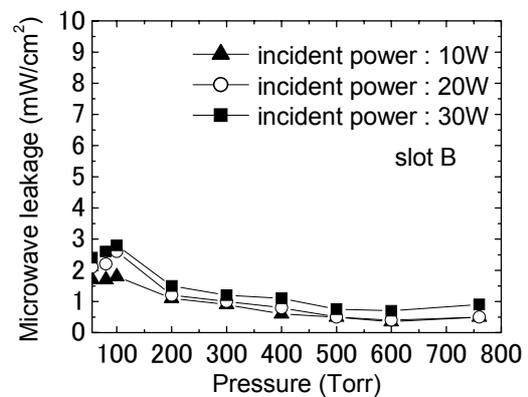


Fig.4 The microwave leakage from the lamp filled with Argon for the slot B

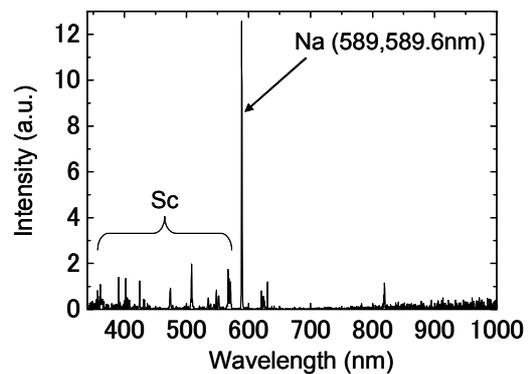


Fig.5 The spectral distribution of the lamp filled with Ar, NaI and ScI<sub>3</sub>

### 4. Reference

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- [2] Weber and R.Scholl: J.Appl.Phys., **74**, (1993) 607.