STUDY OF STRONGLY NON-UNIFORM NON-EQUILIBRIUM MICROWAVE PLASMA IN NITROGEN BY MEANS OF PROBE AND OPTICAL METHODS

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OUTLINE

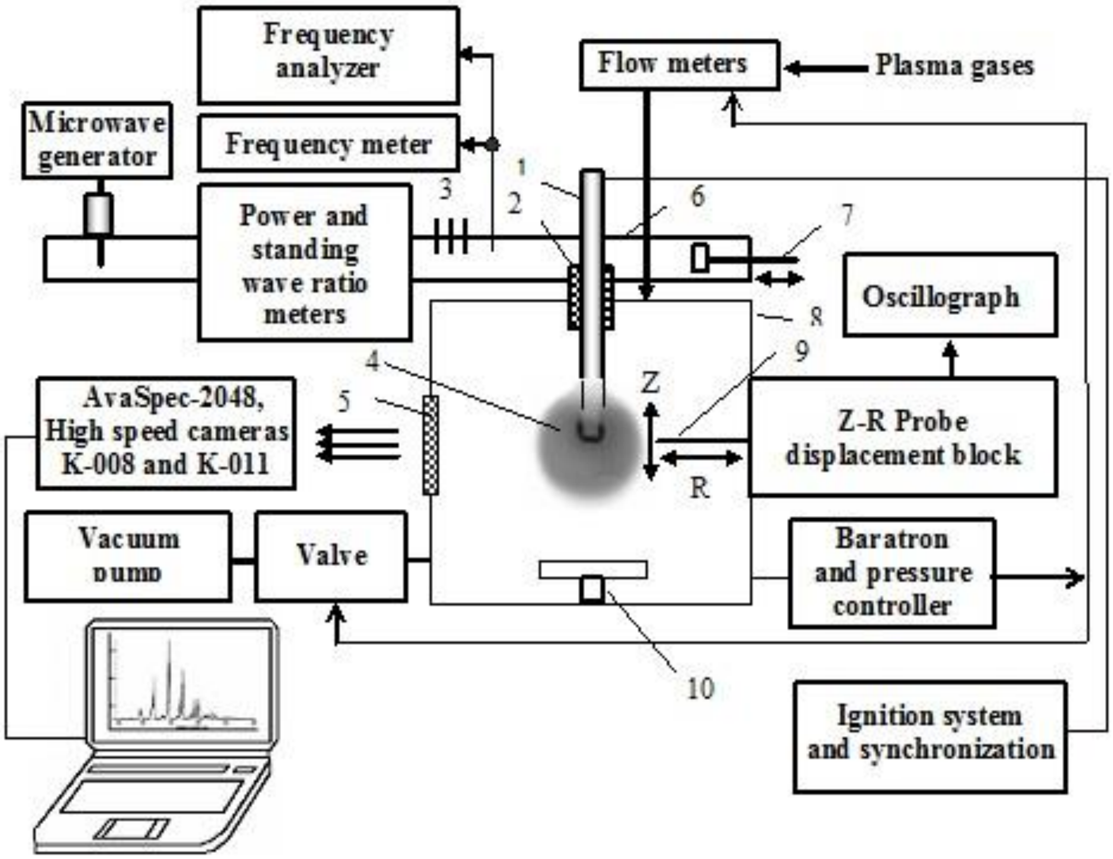
- Introduction
- Experimental setup
- Emission of EMD in visible region
- Results of probe measurements
- Results of optical spectroscopy
- Conclusions

Introduction

- **The electrode microwave discharge (EMD) is a discharge produced in the vicinity of the end of the electrode/antenna in the chamber that is larger than the size of the luminous discharge region. Interest in the study of electrode microwave discharge is caused by a number of reasons. Firstly, EMD is a representative of strongly inhomogeneous discharges and it is important to study the influence of inhomogeneity of the plasma on the physical and chemical processes, as well as the influence of various factors on it. In addition, the primary energy input into the discharge occurs near the electrode / antenna, i.e., the plasma is produced near the surface. Thus it is necessary to study the properties of the plasma to determine the flows of active neutral and charged particles to the surface.**

- **One of the problem is search for methods to control the low temperature plasma properties. One of possibilities is superimposing of external DC field on microwave plasma**
- **This paper describes first stage of the research carried out in this direction. It is devoted to detail study of spatial structure of nitrogen EMD at pressures 1-5 Torr by means of probe and optical emission spectroscopy methods without external DC field.**
- **The further step will be related with study of changes in the spatial structure of EMD under the action of DC field.**

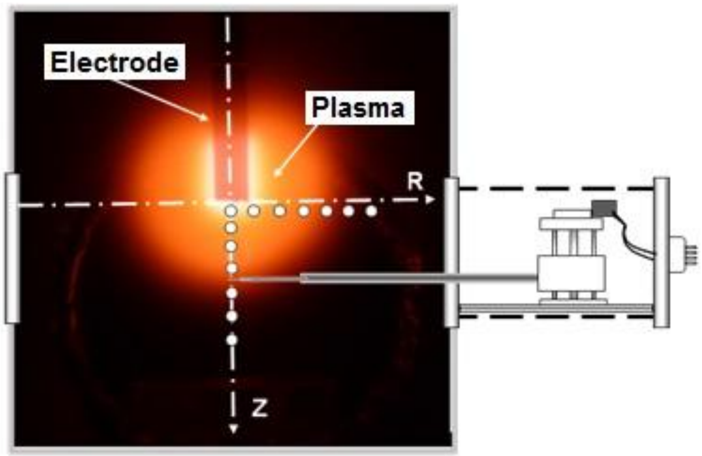
Experimental setup

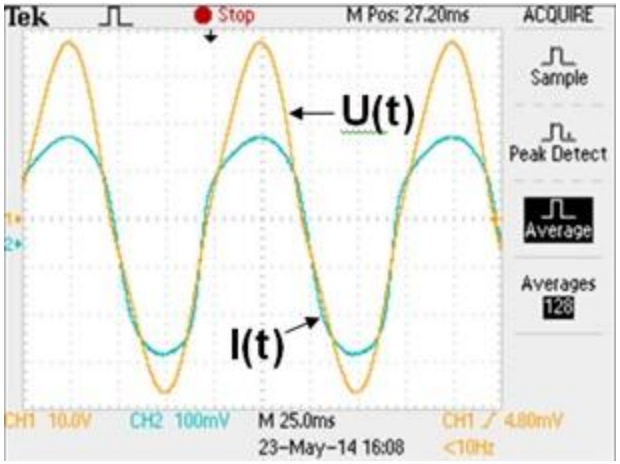


✓**Incident microwave power up to 200 W**
✓**Pressure 1-5 Torr**
✓**Plasma gas flow rate - 80 cm³ / min under standard conditions**

1 – electrode/antenna, 2 – isolator, 3 – 3-slab impedance transformer, 4 – plasma, 5 – optical windows, 6 – waveguide-to-coaxial converter, 7 – shorting plunger, 8 – discharge chamber, 9 - movable double probe, 10 – grounded substrate holder

Experimental setup





Double floating probes: 100 micron tungsten wire in quartz capillaries. The length of each probe is 2.1 mm, the distance between the probes of 2.8 mm. Resistors 20 kOhm were the microwave filters.

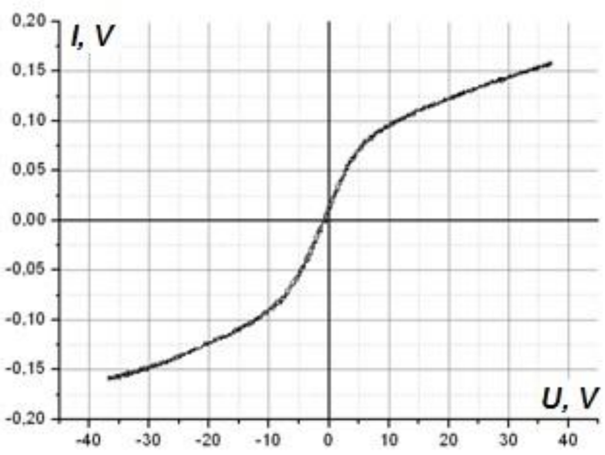
Axial probe displacement: 30 mm with the step of 0.1 mm **Radial probe displacement:** 23 mm with the step of 0.15 mm.

Probe voltage: Sinusoidal signal of frequency 10 Hz and an amplitude of ± 40.

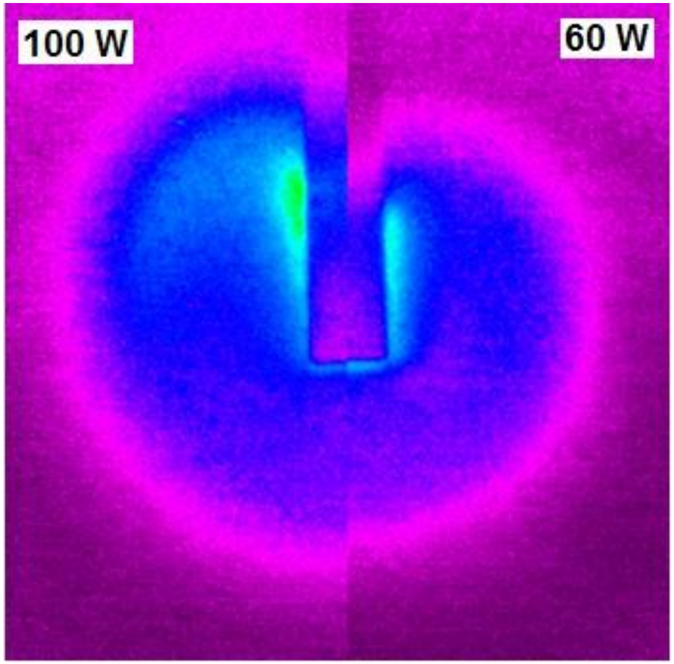
Measuring resistor: 5.6 kOhm

Oscillograms of probe current and voltage were recorded using a double beam oscilloscope with ground isolated channels.

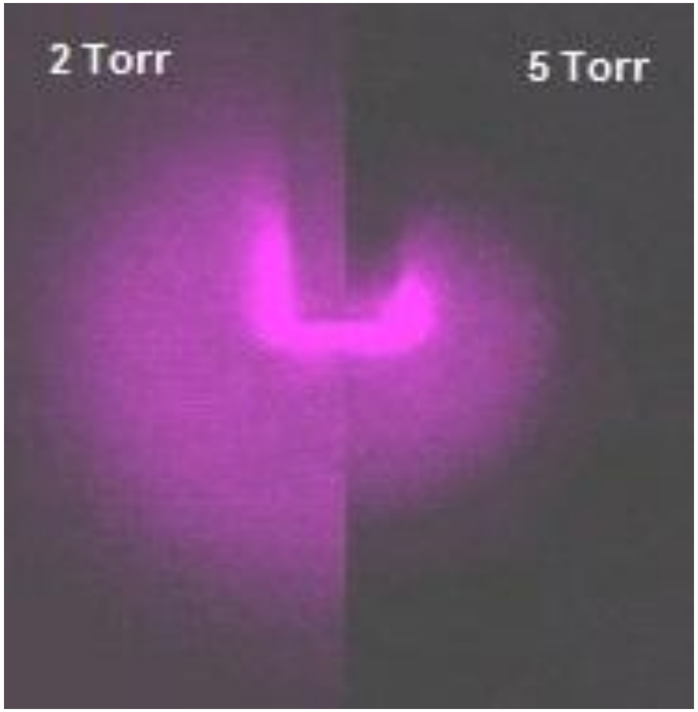
The probe voltage-current characteristics were performed with the help of built-in functions of the oscilloscope.



Visualization of EMD



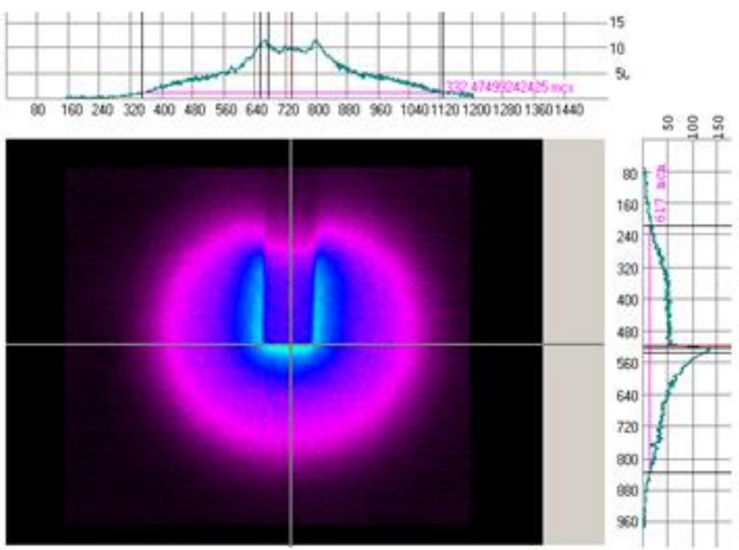
Dependence of EMD structure on incident microwave power at pressure 1 Torr



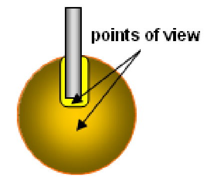
Dependence of EMD structure on pressure at incident microwave power 60 W

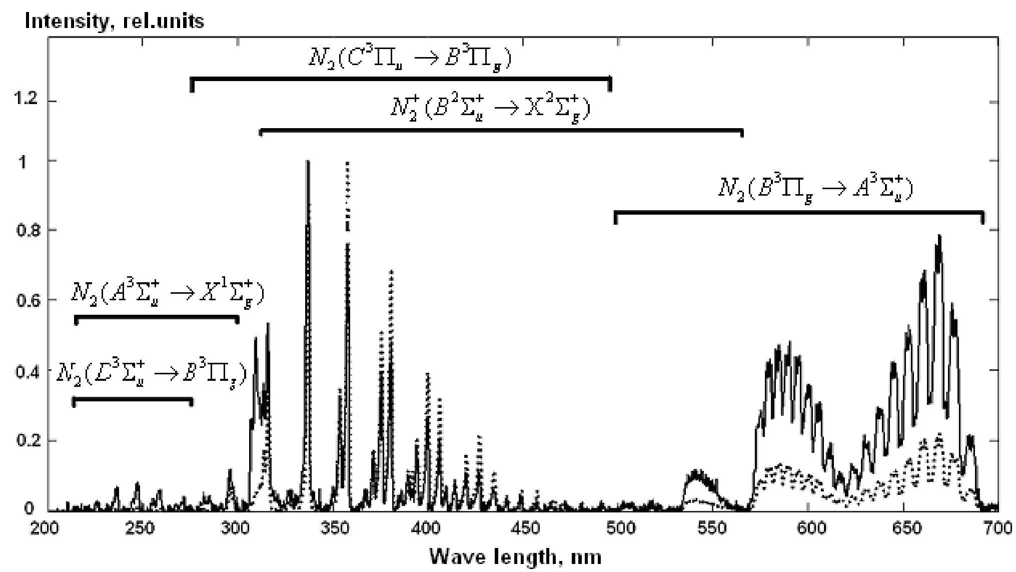
Emission of EMD plasma

Photograph of nitrogen EMD at pressure 1 Torr and axial and radial distributions of discharge emissivity in visible region of spectrum

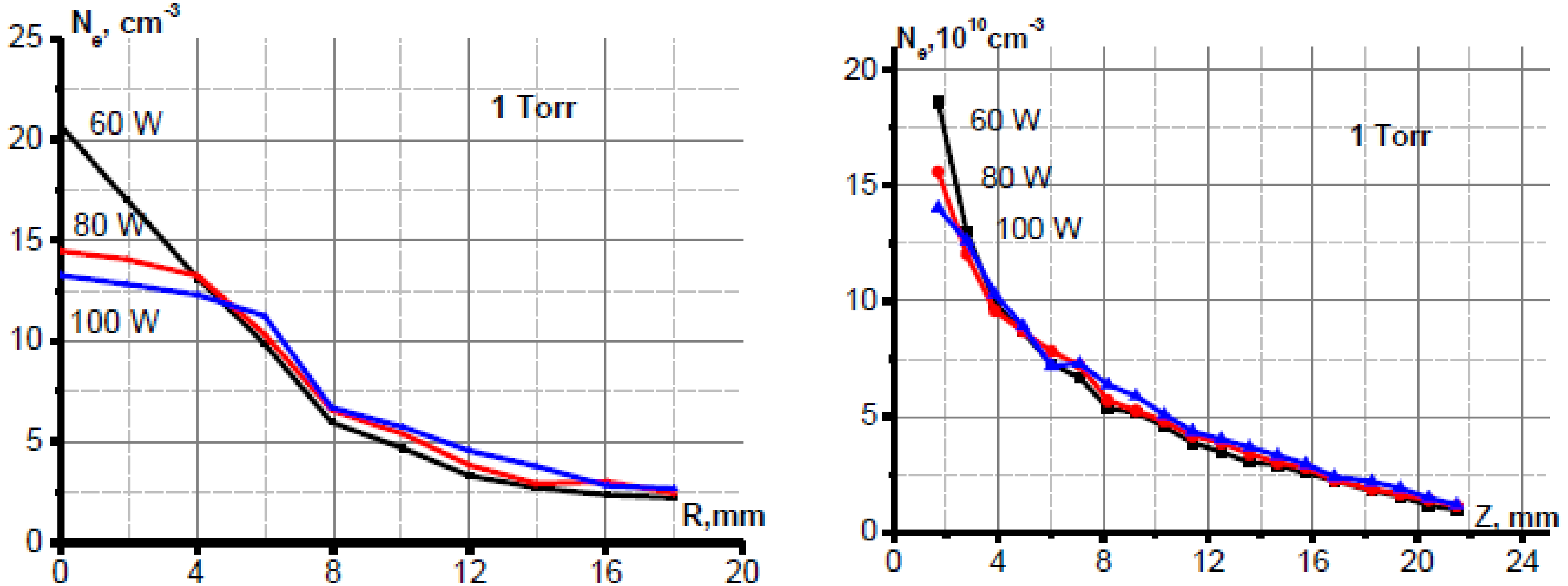


Spectra of nitrogen EMD in the near electrode sheath (dotted line) and in spherical part (solid line)





Results of probe measurements

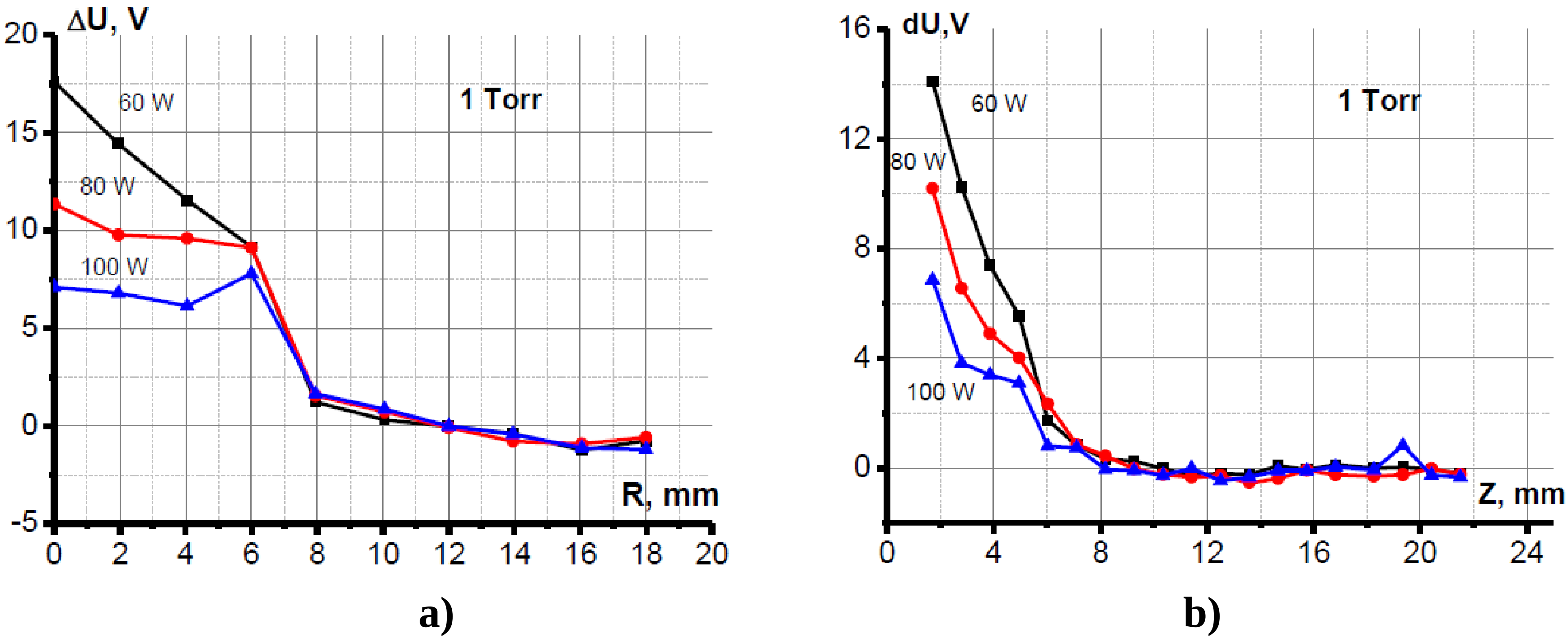


a) b)

Radial (a) and axial (b) distributions of charged particles density at pressure 1 Torr

Electron temperature does not depend on the microwave power. It has flat profile with values 3.5 – 4.0 eV in the antenna region up to 6 mm directions, and then falls up to 2.5 eV at the distance 8 mm and slightly decreases to 2 eV with further increase in the distance.

Results of probe measurements



Radial (a) and axial (b) distributions of DC voltage between two probes at pressure 1 Torr

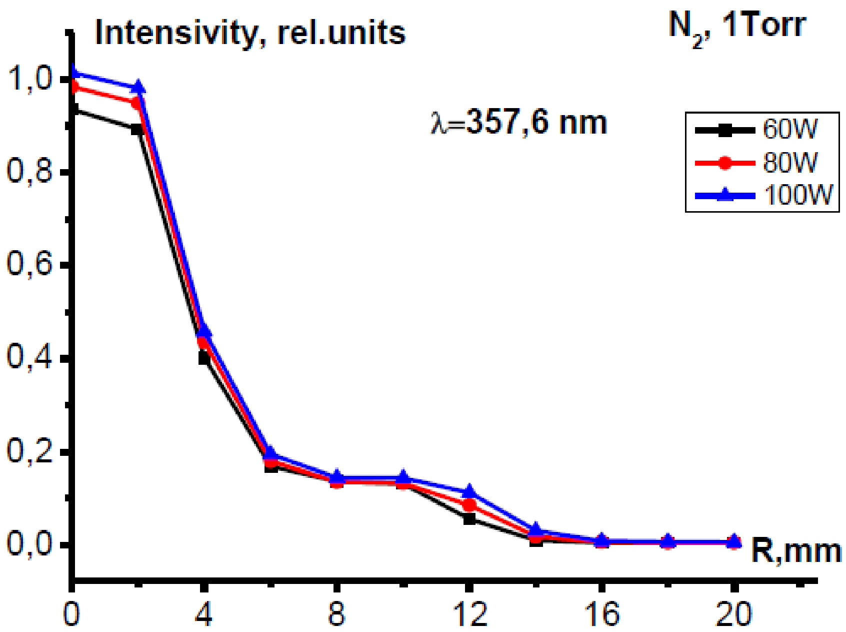
<u>These results have not only one interpretation:</u>

a) **It is real distribution of DC field**

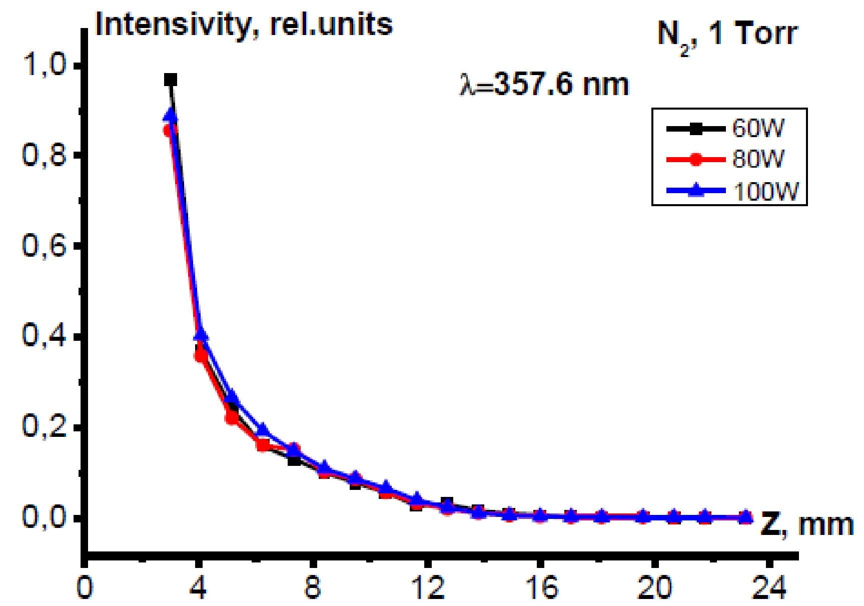
b) **It is consequence of influence of microwave field non-uniformity on the probe measurements**

Additional analysis is necessary

Results of emission spectroscopy



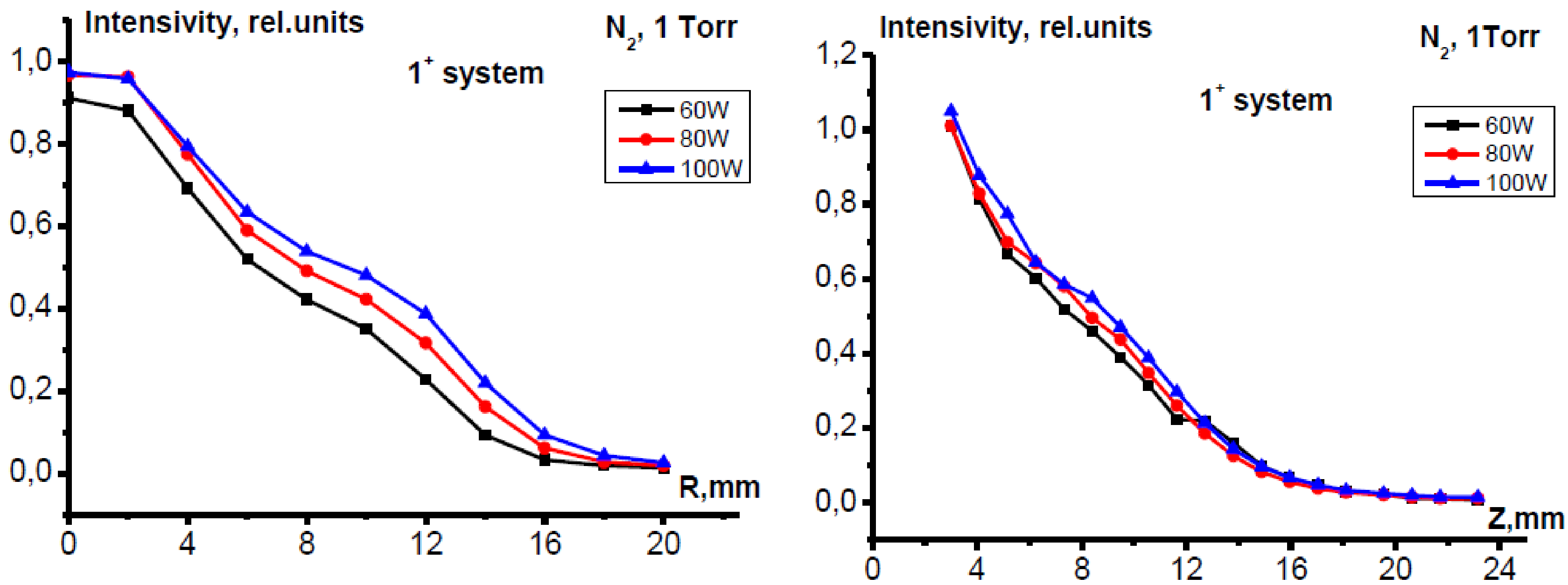
a)



b)

Radial (a) and axial (b) distributions of intensity of the 2^+ band at pressure 1 Torr

Results of emission spectroscopy



a) **b)**

Radial (a) and axial (b) distributions of intensity of the 1^+ band at pressure 1 Torr

Conclusions

- ✓ **Detailed spatial distributions of parameters of electron component of EMD and discharge emissivity give general dependencies of plasma properties on gas pressure and incident microwave power.**
- ✓ **Both the probe results and results of emission spectroscopy showed difference in distributions of plasma parameters in radial and axial directions.**
- ✓ **The main goal was study of possibilities of control the plasma parameters near the substrate holder.**
- ✓ **It was shown that plasma properties in this region are practically independent of the incident power keeping the same the pressure.**
- ✓ **Decreasing the pressure leads to increase the plasma density and concentration of excited particles at the same incident power.**

❖ **ASKNOWLEDGMENTS**

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Thank you for your attention