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# INFLUENCE OF THE GEOMETRIC FACTORS ON COAXIAL DISCHARGE CHARACTERISTICS

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## Introduction

A low-pressure coaxial discharge is investigated theoretically on the base of one-dimensional axial fluid model. This type of surface-wave-sustained plasma (SWP) source is relatively new in comparison to the classical cylindrical plasma column sustained by an electromagnetic surface wave. In the coaxial structure the dielectric tube is filled with air at normal pressure and a metal rod is arranged at its axis (Fig. 1). The plasma is produced outside the dielectric tube in a low-pressure chamber [1,2] by an electromagnetic wave travelling along the plasma–dielectric interface. The plasma is both radially and axially inhomogeneous. It is also possible to produce plasma at free space (at atmospheric pressure) without discharge chamber. In all cases the main part of the coaxial structure is the metal rod, the dielectric tube and the plasma outside the tube.

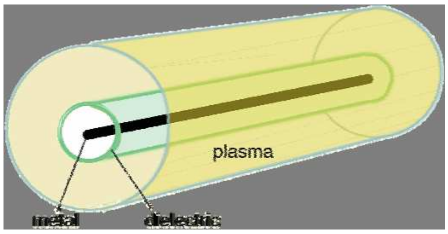


*Fig. 1.Coaxial discharge structure*

In this paper we have investigated theoretically the role of metal rod and dielectric tube radii on the wave and plasma characteristics on the base of one-dimensional axial model.

## Basic assumptions and relations in the model

In our modelling we consider the stationary state of a plasma at low pressure sustained by azimuthally symmetric EM wave ($\omega/2\pi$ =2.45 GHz) travelling along the plasma–dielectric interface. A radially averaged electron number density is used and we also assume that the plasma density, the wave number $k_z$ and the wave amplitude are slowly varying functions of the axial coordinate. The plasma is considered as a weakly dissipative medium and the collision term in the plasma permittivity is neglected.

The theoretical model is based on the local dispersion relation and the wave energy balance equation obtained from the Maxwell's equations [3]. The phase diagrams (the dependence of the normalized electron number density on the dimensionless wave number) and the axial profiles of the wave and plasma characteristics are obtained. The axial and the radial variations of the wave field components are also calculated. Three parameters characterise the geometry of the coaxial structure. They are presented in Table 1:

Table 1

| Geometric factors | Notations | Parameters |
|---|---|---|
| Plasma radius | $R$ (outer radius of the glass tube) | $\sigma = \omega R/c$ ($c$ is the speed of light) |
| Dielectric tube radius | $R_d$ (inner radius of the glass tube) | $\gamma = R_d/R = 1 - d/R$ |
| Tube thickness | $d = R - R_d$ | |
| Radius of the metal screen | $R_m$ | |
| Vacuum space between the tube and the metal screen | $l = R_d - R_m$ | $\eta = R_m/R = \gamma - l/R$ |

We have investigated two dielectric tubes with outer radii 1 cm and 2.4 cm corresponding to $\sigma = 0.513$ and $\sigma = 1.23$ and $\gamma$ is assumed to be the same ($\gamma = 0.85$). At fixed radii of the dielectric tube (resp. $\sigma$ and $\gamma$) the thickness of the metal rod (parameter $\eta$) is varied.

## Results and discussion

Figures 2 a,b and 3 a,b show strong dependence on the metal rod thickness for both values of $\sigma$. One can see that at small values of $\eta$ (thin metal rod) the phase diagrams are crossing the $1/\sqrt{1+\varepsilon_d}$ line which corresponds to the resonance values of the plasma density $n_{res} = 1 + \varepsilon_d$ where $\varepsilon_d$ is the dielectric tube permittivity. They are passing through the region above this line where $n_e < n_{res}$ (underdense plasma) and a region of backward wave propagation appears after the maximum of the curve. The calculations show that at the maximum of the phase curve the wave power becomes zero and in the region of the backward wave propagation it is negative. This means that the plasma exists only in the region of the forward wave propagation and the real end of the plasma column is at the maximum of the phase curve. With increasing the metal rod thickness the phase diagrams move down, which corresponds to increasing of the plasma density. There is no more a backward wave propagation and underdense plasma region which can be seen also from the axial plasma density profiles (figures 2,3 b) at the same discharge conditions.

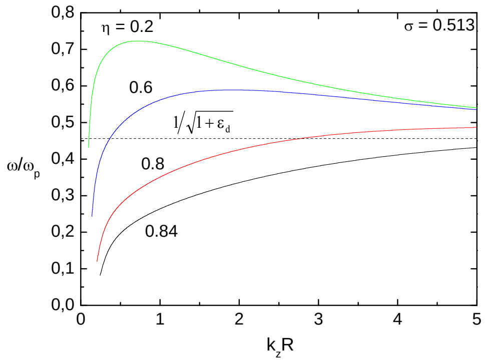


*Fig. 2a. Phase diagrams at σ = 0.513, γ = 0.85 and various metal rod thicknesses*

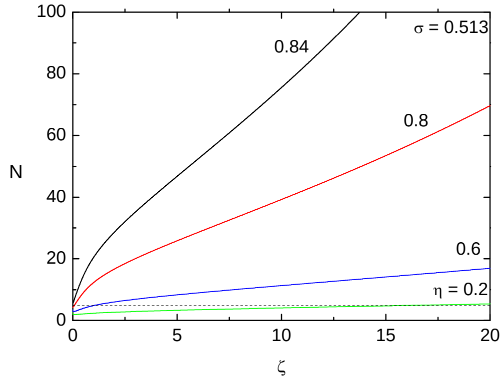


*Fig. 2b. Plasma density axial profiles at σ = 0.513, γ = 0.85 and various metal rod thicknesses*

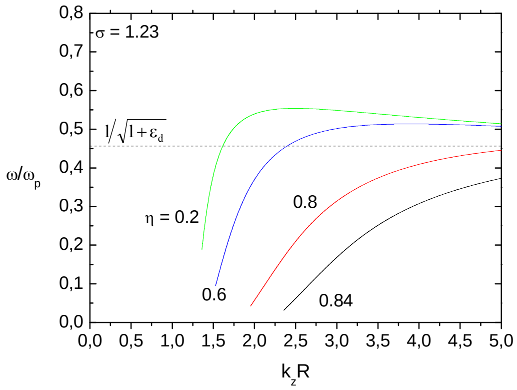


*Fig. 3a. Phase diagrams at σ = 1.23, γ = 0.85 and various metal rod thicknesses*

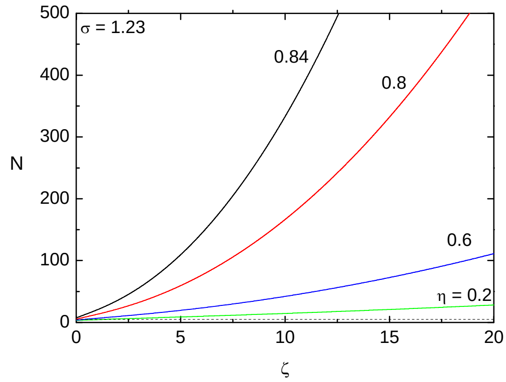


*Fig. 3b. Plasma density axial profiles at σ = 1.23, γ = 0.85 and various metal rod thicknesses*

The dependences on both σ and η are presented in figure 4 a,b. The best conditions for plasma creating and highest plasma density are at high values of σ and η, i.e. a wide tube with thick metal rod inside (σ = 1.23, η ≥ 0.8). When the tube radius is smaller (σ = 0.513) but the metal rod inside is thick (η = 0.8) the plasma density is higher than at wide tube with thin metal rod inside (σ = 1.23, η = 0.2). The worst conditions for plasma creating and lowest plasma density are at tube of small radius with thin metal rod inside (σ = 0.513, η = 0.2).

The axial profiles of the dimensionless $E_z$ wave field component are plotted in figure 5 at the same conditions as in figure 4. ($E_r$ component is much smaller than $E_z$.) One can see that at dielectric tube of small radius (σ = 0.513) the electric field is almost constant along the plasma column and smaller than 1 both for thin and thick metal rod inside the tube. When the dielectric tube is wider (σ = 1.23) the electric field is higher than 1 and decreases significantly along the plasma.

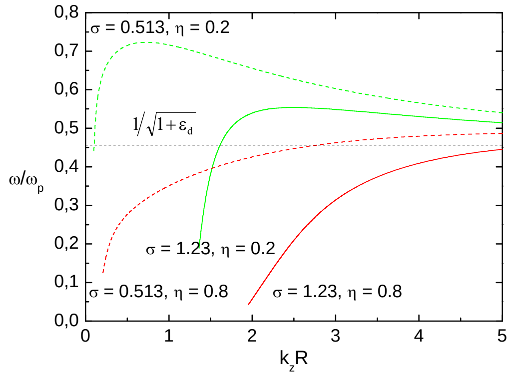


*Fig. 4a. Phase diagrams at γ = 0.85 and various plasma radii and metal rod thicknesses*

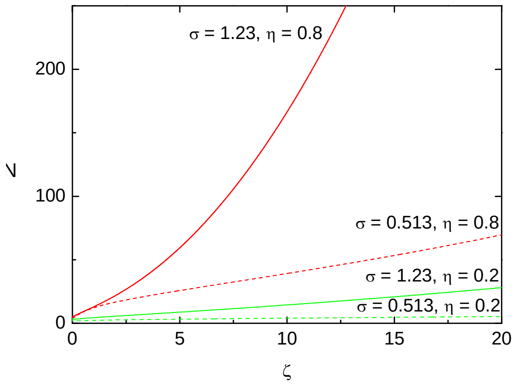


*Fig. 4a. Plasma density axial profiles at γ = 0.85 and various plasma radii and metal rod thicknesses*

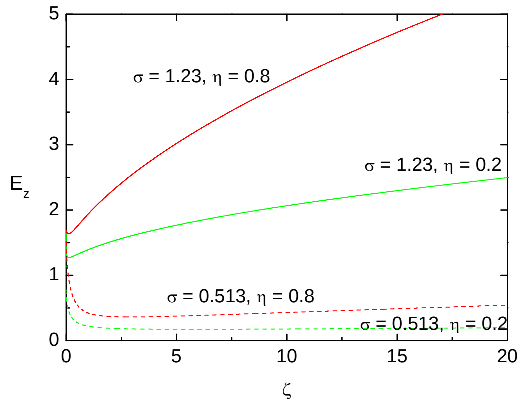


*Fig. 5. Electric field z-component axial profiles at γ = 0.85 and various plasma radii and metal rod thicknesses*

## Conclusion

A strong dependence of the wave and plasma characteristics on the plasma radius and the radius of the metal rod inside the dielectric tube is found out. It is possible to create plasma with higher electron number density just replacing the metal rod inside the tube with a ticker one. As closer is it to the dielectric tube as higher the plasma density is. Varying the geometric factors it is possible to find the most appropriate plasma parameters for a given application of the coaxial discharge.

## Acknowledgments

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## References

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