Determination of arbitrary EEDF of atmospheric-pressure plasma by OES continuum emission spectrum analysis

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Electron information is key to understanding the behavior of atmospheric-pressure non-equilibrium plasma. Numerous new processes and applications involving this plasma have been investigated in recent years. To support these developments, simple and accessible diagnostics methods are required, which are limited for atmospheric-pressure plasmas.

In the method presented, the arbitrary EEDF (electron energy distribution function) will be determined using only OES (optical emission spectroscopy) measurement [1,2]. This arbitrary EEDF is constructed numerically rather than by using a function basis (e.g. exp(-T_e) for Maxwellian or exp(-T_e^2) for Druyvesteynian EEDF models). As such, this EEDF is purely based on experimental data, which is the OES continuum spectrum. For this type of plasma, the OES continuum spectrum is mostly dominated by neutral bremsstrahlung [3], which is a free-free interaction between an electron and a neutral particle. During this interaction, momentum is exchanged between the two particles, which results in the emission of a photon. The energy of the neutral bremsstrahlung photons can be related to the EEDF as follows:

$$\varepsilon_{ea}(h\nu) = \int_{h\nu}^{\infty} R(h\nu, E) f(E) dE.$$

Here the variables $h\nu$ and E are the photon energy and electron energy respectively. $\varepsilon_{ea}(h\nu)$, $f(E)$ and $R(h\nu, E)$ are the neutral bremsstrahlung emissivity, EEDF and the kernel function. The neutral bremsstrahlung emissivity is obtained from OES measurement and the kernel is a known function. This integral equation is solved inversely to obtain the EEDF. Due to the integral bounds and complexity of the kernel equation, conventional inversion methods are not successful. Therefore, machine learning is used to reconstruct the EEDF. A genetic algorithm is used to obtain the EEDF through iterative guessing and data analysis.

In order to evaluate this method, verification is necessary. For these results, a known EEDF (a Druyvesteyn EEDF with T_e = 1 eV) is used to create a verification dataset of an OES measurement between 300-800 nm wavelength. This dataset is given to the genetic algorithm as input. Its output can then be compared to the original EEDF.

As can be seen in figure 1, detailed results with a mean absolute error around 3% can be obtained within reasonable time using a realistic OES measurement range. When necessary, this error can be reduced further by increasing calculation time. Concluding, a new method to determine arbitrary EEDF for atmospheric-pressure plasma is presented that uses only OES measurement, making it a very accessible diagnostics method.

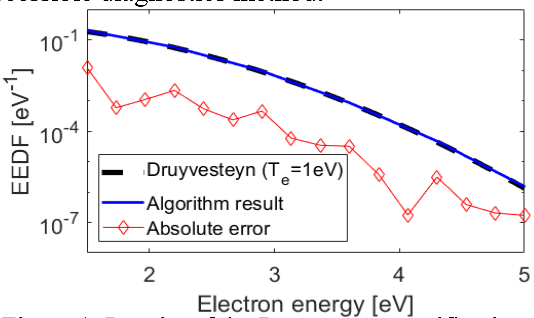

Figure 1: Results of the Druyvesteyn verification case after 2-3 minutes processing.

References

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