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PRACTICAL EXPERIENCE WITH THE MEASURING OF THE SPECTRAL LINE PROFILE BY MEANS OF THE FABRY—PEROT INTERFEROMETER[1]

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In the paper presented the influence of the individual parts of the fast scanning Fabry—Perot interferometer on the shape of the spectral line profile is studied. The right adjustment, the choice of the working diaphragm, the choice of the exposition time are discussed. It is shown that the usually recommended way of adjustment does not give reproducible results.

I. INTRODUCTION

The Fabry—Perot interferometer is a very useful equipment for the spectroscopical investigations of plasma because it makes possible to determine the initial (theoretical) profile of the spectral line emitted by plasma. Assuming its analytical form we can evaluate, for example, the temperature of the neutral particles or sometimes the density of the charged particles in plasma. In many cases the Fabry—Perot interferometer is the only applicable equipment and therefore it is very difficult to verify the results of measurement. For this reason we must give proper attention to the individual parts of measurement and to its processing. Otherwise, the results obtained in this way may be full of errors or be altogether useless. Unfortunately, little exact information on proper work with the Fabry—Perot interferometer has been published. As the most important data are about the setting of the interferometer, the choice of the working diaphragm and the exposition time of the spectral line profile, they advise how to verify the stability of the measuring apparatus function so that it may correspond to up-to-date measurements in plasma physics.

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At our department the Fabry-Perot universal interferometer UFPI, manufactured by Carl Zeiss Jena, has been used to determine plasma parameters for several years. Adaptations of the interferometer were suggested and made, so as to shorten the exposition time of the line profile in a suitable way [2]. Using the digital equipment we also modernized the registration of the profile. Our experience with the computer processing of the measured data was presented in [1]. In the present paper we should like to summarize our experience obtained during measurements with the UFPI.

II. EXPERIMENTAL ARRANGEMENT

The UFPI uses a piezoeffect to scan the line profile (Fig. 1). The corresponding range of the spectra is chosen by means of the SPM 2 monochromator. The signal is registered by a photomultiplier. Using a low scanning velocity it is possible to display the signal on the recorder. For a shorter measuring time we must use the OPD 604 oscilloscope and the OPJ 619 memory cartridge. In this case the analog signal is converted into digital form with the subsequent display on the TV screen. Afterwards a lasting copy of the screen picture may be also made on the recorder. The exposure of still shorter signals requires the OG2-21 memory oscilloscope by RFT. The schematic block drawing of the experimental set-up is in Fig. 2. More information on these adaptations is in [2].

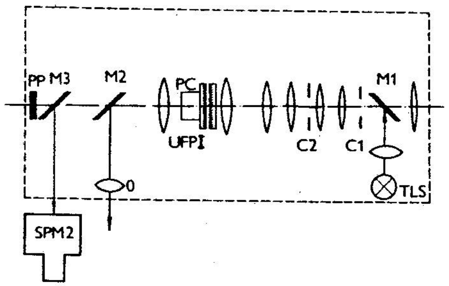

Fig. 1. Main parts of the UFPI from Carl Zeiss Jena. M1, M2, M3 ... movable mirrors; PC ... piezoceramics element; PP ... photoplate; TLS ... testing light source; O ... eyepiece making it possible to observe the interference picture.

According to the producer the C1 input diaphragm ought to have a minimal value during the measurement. The C2 circular diaphragm may be changed within the diameter range of 0—20 mm. The input slit of the monochromator is 20 mm high and its width can be changed from 0 to 1.5 mm. The diaphragm is not strictly rectangular, but has a slightly concave form. The height of the input slit of the monochromator and the width of its output slit are changed simultaneously. As we mentioned above it is possible to choose the exposure time of the spectral line profile. Now this registration may be reduced from

several hours to 10 ms. As a testing light source the CdE TGL 200-8175 cadmium discharge tube was used. Contrary to a standard connection, a DC power supply was applied for the lamp to prevent a light oscillation of the lamp with mains frequency.

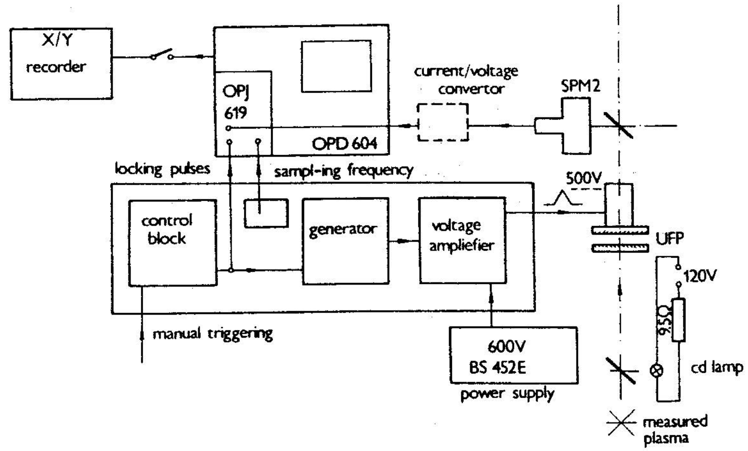

Fig. 2. Schematic block drawing of the experimental set up.

III. EXPERIMENTAL RESULTS

III. 1. Adjustment of the Interferometer

Adaptation realized by us made it possible to carry out a great number of measurements and to test those parameters that would take too long to get measured. Besides, the adjusted parameters of the interferometer do not remain constant during that time.

We have read in the UFPI manual that first the interferometer must be adjusted roughly, observing the interference picture. Then we adjust the interferometer so that the centre of this picture has one colour. However, it follows from our measurements of the apparatus function width that the recommended adjustment is not very reliable and that the measured profiles have a different width even though the centre of the mentioned picture has one colour. If it is possible to register the line profile for several seconds it appears to be most suitable to continue the adjustment further so that the halfwidth of the line may have a minimal value. As we show further the change of the C2 diaphragm has small influence on the halfwidth measured spectral line providing that a sufficiently correct adjustment is made. We must remark that the apparatus function is stable for several hours of careful work with this type of interferometer.

For this reason it is always suitable to measure in the first place the Cd line profile before the proper diagnostics. Then we measure twice the profile of the line emitted by the plasma and afterwards the Cd profile again to find whether the adjustment has remained unchanged.

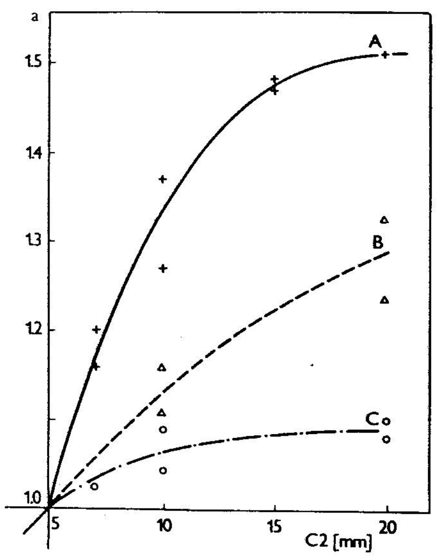

Fig. 3. The halfwidth of the apparatus function as a function of the C2 diaphragm diameter (related to the halfwidth at C2 = 5 mm).

Especially in the case of the scanning velocity below 1 minute we must eliminate the influence of external mechanical vibrations from the surroundings. In the original arrangement the external vibrations were suppressed by the recorder having a high value of the time constant in fact. Even though the profiles obtained under these conditions have no observable noise it is not possible to underestimate the influence of vibrations in this case, because the stability of the adjustment greatly decreases.

In our case we used 6 pneumatic springs for the through elimination of the vibrations.

III. 2. The influence of the input monochromator slit on the apparatus function width

From theoretical considerations concerning the apparatus function presented in [3] it follows that both the increase of the input monochromator slit and the C2 diaphragm result in the increase of apparatus function width. Those calculations were made for the circular diaphragm having a considerable influence on

the apparatus function. However, we have demonstrated that the halfwidth of the line increases about 6 % changing the width of the slit from 0.1 mm up to 1.5 mm. In the most used range from 0.5 mm to 1.0 mm the halfwidth changes only about 2 %. From that it follows that it is not suitable to measure with a narrow input slit of the monochromator due to a small signal/noise ratio, in contrast to theoretical papers.

III. 3. The influence of the C2 diaphragm on the apparatus function

From theoretical computations for the Fabry—Perot interferometer [3] it follows that light intensity increases in the maximum of the line profile with a simultaneous increase of the diameter of the C2 diaphragm. This fact may be explained in a first approximation as follows. The diaphragm delimitates a diameter of the light beam incident on mirrors of the interferometer. Therefore, with the increase of the diaphragm the quality of the border parts of the mirrors plays a major role. At the same time the real mirrors have imperfections which are the larger, the larger the surface of the mirrors is. Since a serious lack of the Fabry—Perot interferometer is also the fact that the mirrors are not exactly parallel it means that a worse adjustment manifests itself in a larger influence of the C2 diaphragm on the halfwidth of the apparatus function. It can be seen in Fig. 3 clearly. The quantity a is the Cd halfwidth divided by the halfwidth at C2 = 5 mm measured under the same conditions, which characterizes better the influence of the C2 diaphragm. The A dependence illustrates a normal adjustment observing only the interference picture. Results of the method described above are plotted as B. This method was used during a normal measurement. The C curve shows one of the best settings of the UFPI. However, it is very difficult to achieve this and it is impossible to keep the stable adjustment for a longer time.

III. 4. The Influence of the exposure time on the accuracy of measurement

Using a high scanning velocity the profile can lose its symmetry and a broadening of the profile may occur. For this reason the influence of the detector time constant and the exposure time on the apparatus function were followed in [3]. In our case these changes are negligible. Nevertheless we must carefully choose the scanning velocity in the diagnostics of discharges. The exposure time must be always short in order that the parameters of discharge may be constant. Otherwise, badly ascertainable distortions of the profile may occur. With increasing scanning velocity the ratio of useful signal and noise decreases, i.e. plasma parameters may be determined with less precision. From this it follows that it is very necessary to have the possibility to choose the exposure time in a wide range.

IV. CONCLUSION

For plasma diagnostics by means of the UFPI it was necessary to modernize our registration of the line profile, to shorten the exposure time and to improve the damping of external vibrations acting on the UFPI.

In this way the modernized interferometer made it possible to investigate more precisely the influence of the individual parts of the experimental set-up on the accuracy of measurement. The results obtained from those experiments and during many years of work with the UFPI are summarized in this paper.

Here, we explain the proper way of the UFPI adjustment, the problems with the choice of the working diaphragm in the inteferometer and monochromator, the influence of the exposure time on the accuracy of measurement, the way of stability checking and the influence of external vibrations on the accuracy of measurement.

Our practical experience shows that the choice of the right parameter setting of the individual parts of the equipment is relatively difficult and very time-consuming and not all theoretical questions have been solved yet, that is why we are not able to evaluate the influence of the measurement errors of the apparatus function and the line profile on the calculated plasma parameters.

Nevertheless, we believe that the so far acquired knowledge will be useful to all those who use the Fabry—Perot interferometer and will enable them to increase the accuracy of measurement and save them many time-consuming experiments.

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ПРАКТИЧЕСКИЙ ОПЫТ ИЗМЕРЕНИЯ ФОРМЫ СПЕКТРАЛЬНОЙ ЛИНИИ ПРИ ПОМОЩИ ИНТЕРФЕРОМЕТРА ФАБРИ—ПЕРО

В данной работе исследуется влияние отдельных частей сканирующего интерферометра Фабри—Перо на форму спектральной линии. Обсуждается правильность юстировки, выбор рабочей диафрагмы и выбор выдержки времени. Показано, что обычно рекомендуемый способ юстировки не дает воспроизводимых результатов.