Laboratory programs on high resolution spectroscopy

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## ABSTRACT

A series of laboratory tests with Fabry-Perot interferometer begins from adjusting of etalon Fabry-Perot and Zeeman effect observation. Then students investigate instrumental profile by thin etalon Fabry-Perot transmission measurement and study lowtemprature plasma emission line profiles by comparing the results of real and computer simulation experiments.

## 1. INTRODUCTION

Fabry-Perot etalon has great significance in high resolution spectroscopy as a simple and convenient instrument.It is important for optical education process too.

Its theory seems to be clear. Students can applicate their theoretical knowleges to explain certain effects they watch dealing with the interferometer. They have also a good chance to understand what the instrumental profile is and observe its influence on experimental results.

Here the series of laboratory programs for our physics department students are described and some questions are presented that they have to answer.

## 2. FIRTS ACQUAINTANCE WITH FABRY-PEROT

At first the student have to assemble etalon Fabry-Perot and simple set up for its adjustment (see Fig.1).

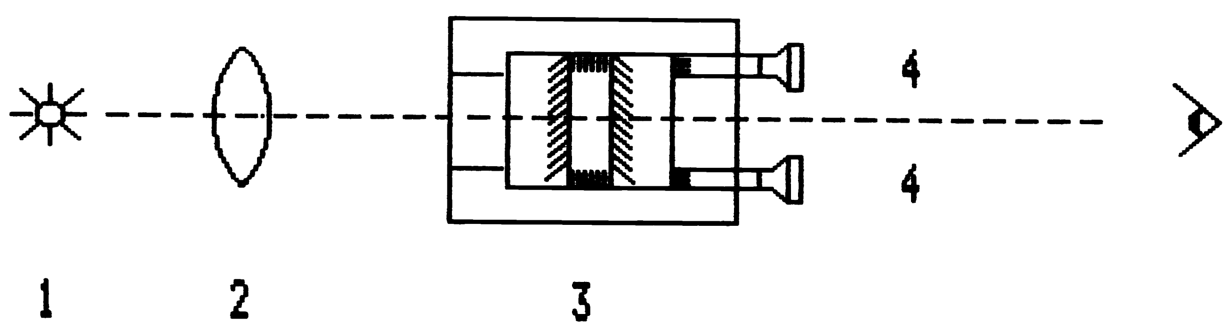



Fig.1. Set up for Fabry-Perot etalon adjustment.
1-mercury gas discharge lamp, 2-lense, 3-Fabry-Perot etalon, 4-screws and springs.

Looking through Fabry-Perot etalon the student sees violet, green and yellow fringes. The center of the fringes always coincides with the image of his pupil.

*What is the reason of this coincidence?*

If the mirrors are not exactly parallel the student discovers that the fringes are squeezing or extending while he is moving his eye up or down, left or right.

*What is the reason of such fringes behaviour?*

The student can change a little the angle between mirrors by manipulation with screws, which change pressure to one of the mirrors. The aim is to make them as parallel as possible.

It is easy to fulfill if the student understands the connection between mirrors distance and fringes space.

## 3. ZEEMAN-EFFECT OBSERVATION

In this and following programs students use the Fabry-Perot etalon placed in front of grating or prism monochromator, which is the part of computer on-line spectral installation (see Fig.2).

Hardware and software of these systems were developed by teams of our department engineers and programmers for education as well as for scientific purposes. Tecnical details will not be descussed here, we´ll be dealing with training applications only.

The first question for student is

*What picture is expected to be seen in exit opening of the spectrometer if exit slit would be put out?*

After this picture observation the students display line profiles on the computer screen and record them at the printer. The examples of these results are presented on Fig 3.

The task for students is to determine magnetic field strength. Fabry-Perot plates separation and wave length is known.

## 4. FABRY-PEROT FREE SPECTRAL RANGE AND INSTRUMENTAL PROFILE

At the begining of this program the student have to answer the question.

*What will you see in the spectrometer exit opening if mercury lamp in our installation (see Fig 2.) will be replaced by filament lamp?*

The first answer is usually: "nothing", then on some reflection: "continuous spectrum"

The next question is

*Does this picture depend on Fabry-Perot and monochromator spectral qualities?*

When the student has understood importance of monochromator resolution and Fabry-Perot free spectral range relationship, he can calculate the plates separation value for spectrum in exit opening not to be continuous.

He is suggested to imagine the picture which would be seen in this case.

The most widespread answer is : "continous spectrum, crossed by several slopping dark strips".

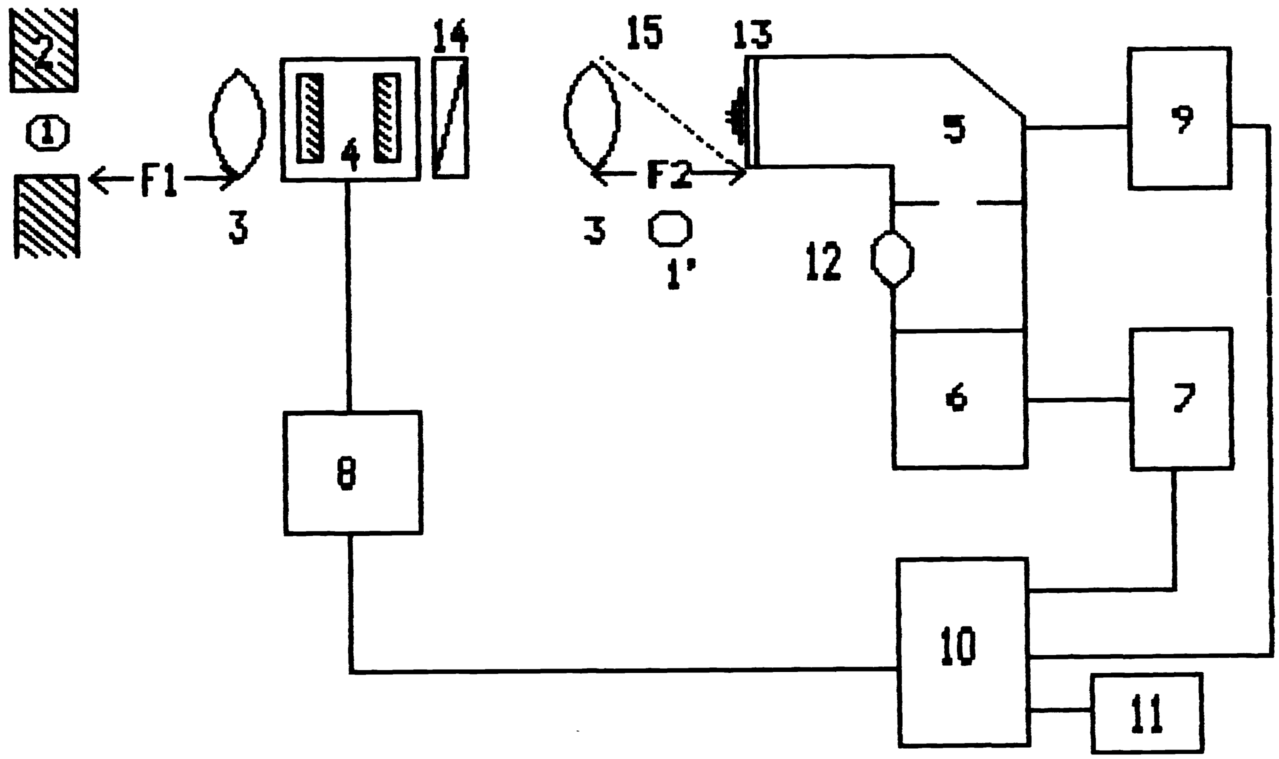
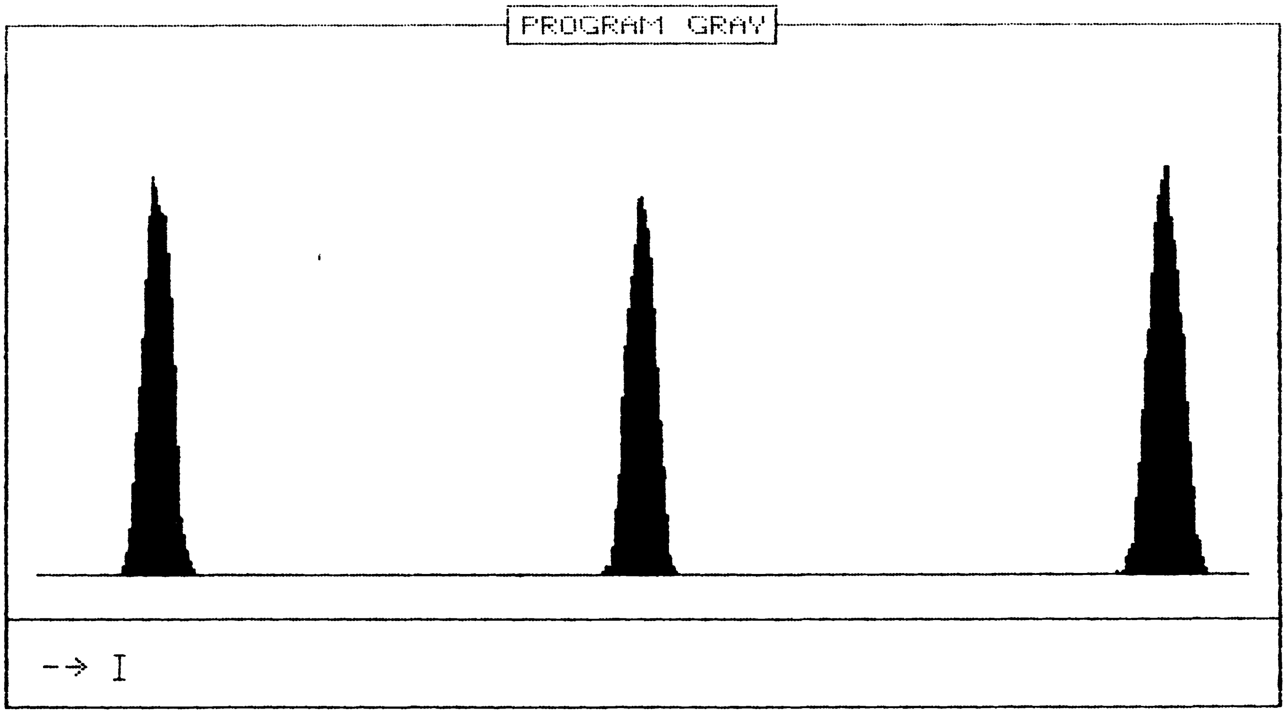



Fig.2. Spectral installalion with Fabry-Perot etalon.

1,1' - light source
2 - magnet (for Zeeman effect observation)
3 - lenses
4 - Fabry-Perot etalon
5 - spectrometer
6 - photoelectrical block
7 - A-D convertor
8 - unit for F-P plates optical distance variation
9 - monochromator scanning unit
10 - computer
11 - printer
12 - eye-piece for spectrometer exit opening observation
13 - slit which is perpendicular to monochromator entrence slit
14 - polarizing filter
15 - half transparent mirror



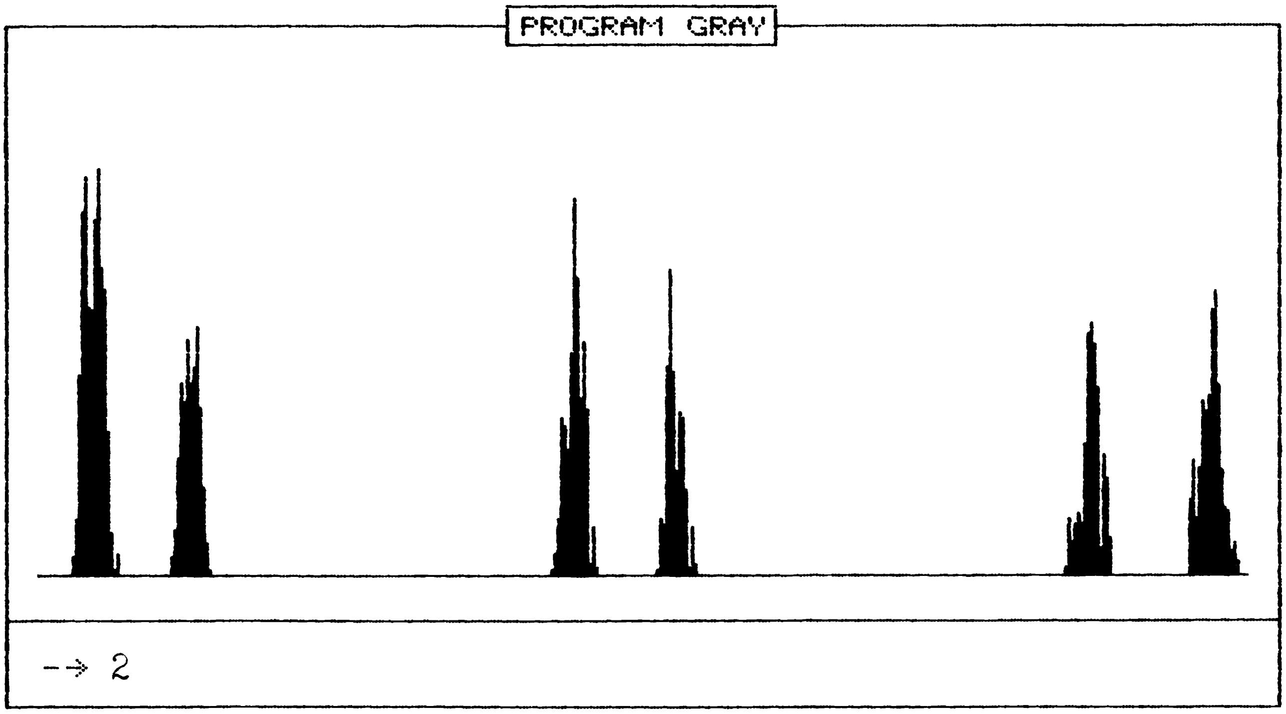




Fig.3. Normal Zeeman effect. Observation is at right angles to the field.
1 – Light polarisation is parallel to the direction of the field
2 – Light polarisation is normal to the field
The separation of the plates t=4 mm.

When Fabry-Perot etalon with plates separation t~0.02 mm is placed in front of the spectrometer, the student notices to his surprize the series of equidistance upright lines, that is monochromatic entrance slit imaginations.

It is good basis to discuss the influence of Fabry-Perot exit opening size on etalon resolution.

As usual we also show the students simple demonstration with Fabry-Perot etalon (see Fig.4.).

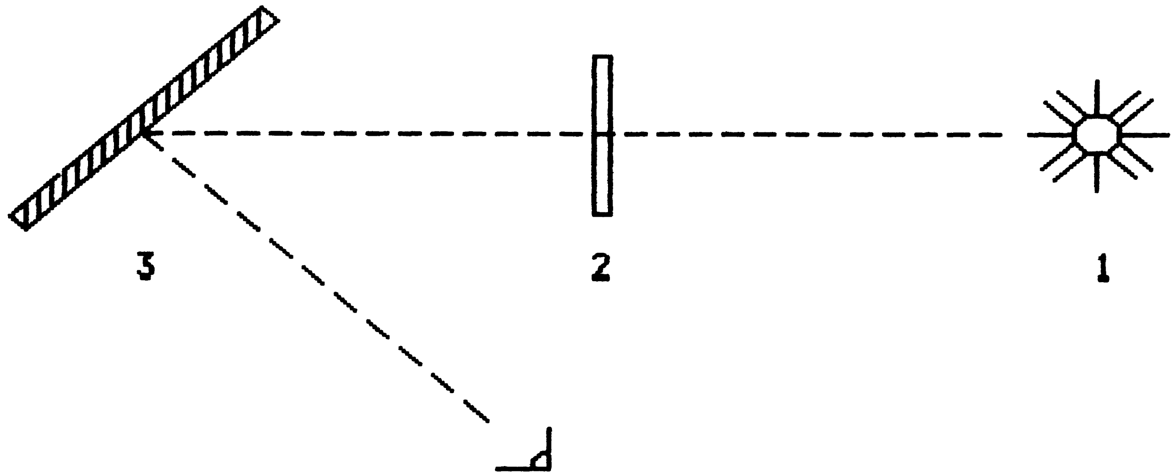



Fig.4. Simple demonstration set up.
1 - filament lamp, 2 - thin Fabry-Perot etalon, 3 - grating.

Without etalon they see brignt continuous spectrum but placing thin (t~0.02 mm) Fabry-Perot etalon between the lamp and the grating they observe the series of bright discrete chromatic filament images.

The last step of this program is recording transmission spectrum of thin etalon by automatic spectral installation ( see Fig.2, filament lamp instead of mercury lamp and magnet ), that is Fabry-Perot instrumental profile .

## 5. FABRY-PEROT REFLECTION SPECTRUM

Changing the mercury lamp position (1′, see Fig.2) and using half transparent mirror (15) the student also can record Fabry-Perot reflection spectrum and compare it with transmission one (Fig.5).

The questions for students are:

*The reflection spectrum is asimmetrical, what is the reason? The sum of reflected and transmited light intensity should be constant, should not it? It is not constant. What about conservation of energy in this case?*

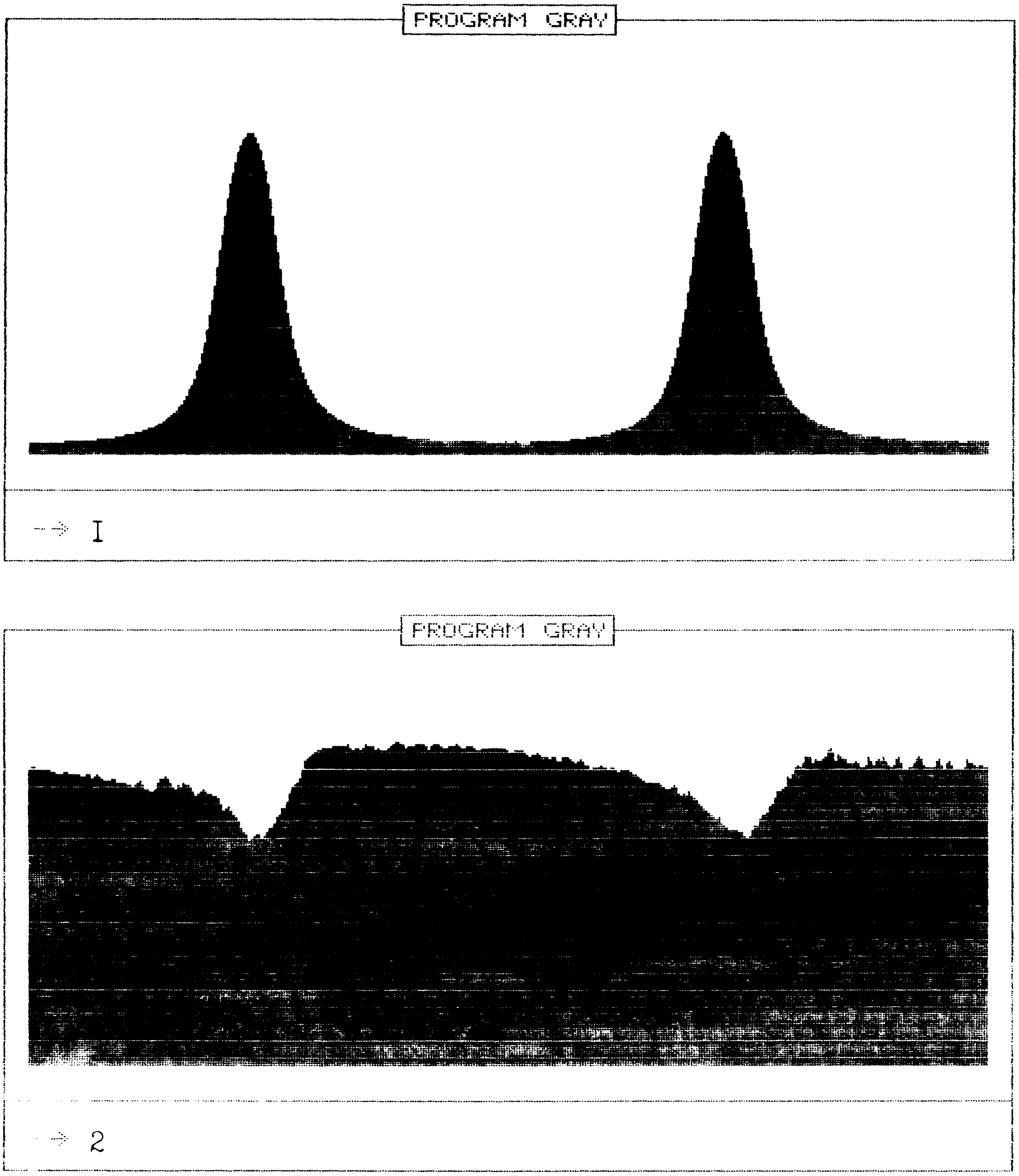



Fig.5. Fabry-Perot transmission (1) and reflection (2) spectra.

Simple Fabry-Perot theory[1], which ignores light absorbtion in mirrors, predicts that etalon reflection and transmission abilities sum is constant.

*It is clear that in this case absorbtion is not negligible, but why does it change within Fabry-Perot free spectral range ?* The reason may be found in thin layers optics theory. Reflection layers are on glass bases. Glass-layer($R_1$) and air-layer($R_2$) boundary reflection coefficients differ in phase. In reflecting spectrum we see the interference of many waves which reflect from air-layer boundary and one wave which reflects from glass-layer boundary. Figure 6 represents computer simulated reflection and transmission spectra.

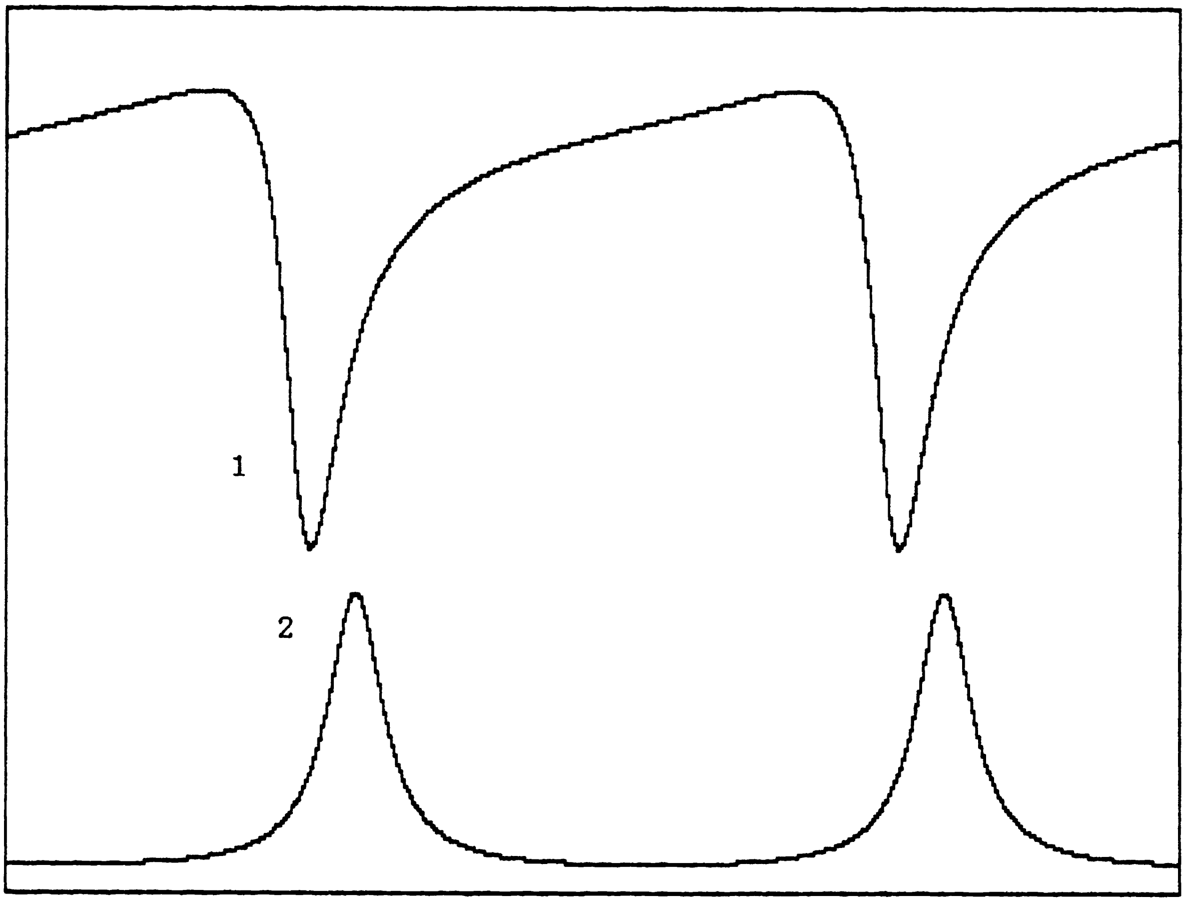



Fig.6. Computer simulated Fabry-Perot reflection (1) and transmission (2) spectra. Absorbtion coefficient a=0.13, $R_1$ and $R_2$ phase difference f=0.6.

## 6. LOW TEMPERATURE PLASMA DIAGNOSTIC

When students have studied the theory of spectral line spreading they can use spectral set up with Fabry-Perot etalon for gas discharge temperature determination by Doppler line broadening. But other line spreading factors and hiperfine line structure have to be taken into acount also[2].

There is a computer program which allows to simulate "experimental" line profile if line structure, plasma temperature, levels life times ( or collision broadening ) and instrumental profile are known.

The students are able to change these parameters of broadening trying to achieve the best coincidence between computer simulated and real experimental profile.

An example of this result is presented on Fig.7.

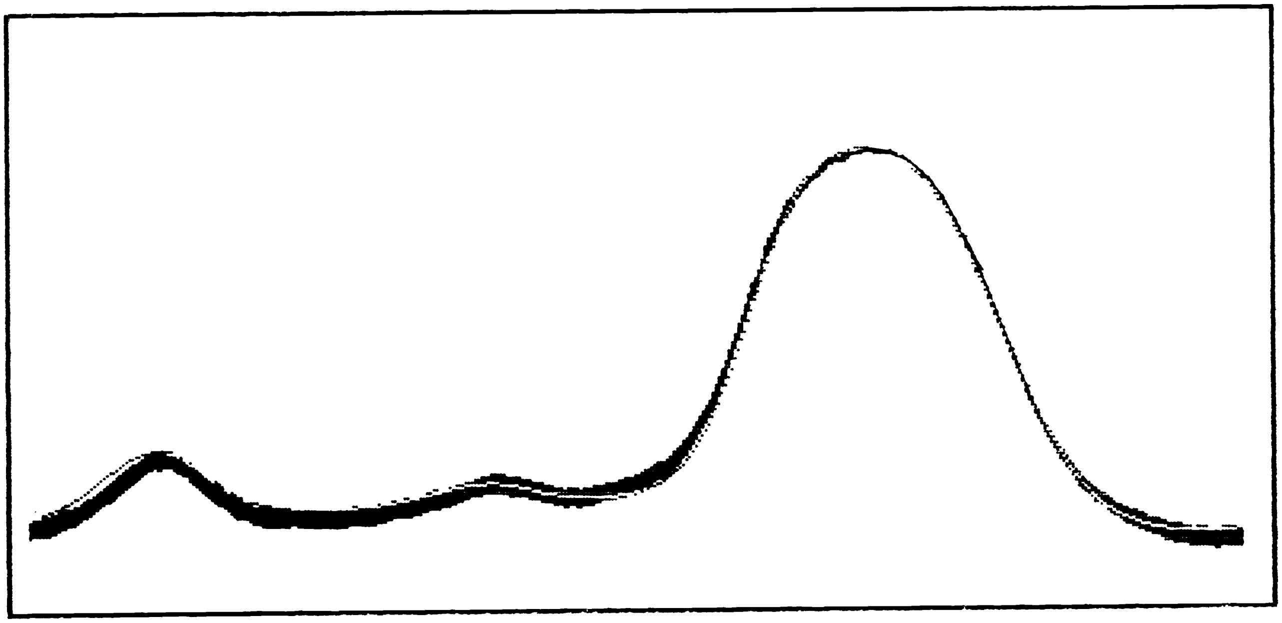


Fig.7. Mercury spectral line (546 nm ).
five experimental profiles averaging, ...... simulated profile.
Line structure, life times and reflectivity of Fabry-Perot plates are assumed to be known. Optical thickness and plasma temperature are to be determined.

So during this series of laboratory programs our students improve their knowledge in physical optics and aquire skills in operating with complicated spectral equipment.

## 7. REFERENCES


1. Max Born, Emil Wolf, *Principles of optics,* Pergamon PRESS, Oxford-London, Edinburgh,New-York, Paris, Frankfurd, 1965.

2. W.Demtroder, *Laser spectroscopy,* Springer Verlag, Berlin, Heidlbeig,New-York, 1982.