Optimization of the reflectivity of Al – SiO_2 multilayer mirror near UV

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Abstract

In this work were built mirrors with multilayer film of aluminum-silicon dioxide, deposited in glass substratum in a RF-Sputtering chamber, with a view to optimize the reflection inside the cavity of a nitrogen laser that operates in the UV region (337,1 nm). It's introduced a theoretical simulation of the variation of reflectivity in function of the number of layers, carrying in consideration the kind of the deposited materials. The results were compared with the obtained using common mirrors of aluminum. When compared with mirrors made only of aluminium, it arrives to the conclusion that multilayer get the upper hand, because they introduce reflectivity four superior times.

Introduction

Since the advent of the laser, this has been being employed in the more several areas of the human knowledge, since the technological until the social. The laser is essential part of several equipament, instruments of industrial use and of research. Nowadays a lot of equipament used in the medical and odontological areas use several kinds and different powers laser as tool. More recently, a nitrogen laser of average power has been framed in this context.

The nitrogen laser is formed by an amplifying optic cavity denominated resonant cavity (*etalon*), composed by two flat mirrors, being one their highly reflector, usually of aluminum or silver. This cavity, besides being a fundamental device for the operation of the laser, is one of the elements that define your efficiency. The detail is that the mirrors of aluminium, used in this cavities, own light absorption high rates (60%), decreasing, this way, the efficiency of the laser, once that her reflectivities will define part of your gain. These reflectors surfaces has of being optimized for the operation frequency of the equipment to guarantee the maximum performance. This work introduces a proposal of maximizing the gain of the laser, using a reflector mirror formed by a multilayer film of Al – SiO_2.

Experimental Setup

The fine films that form a multilayer system are constituted of two materials of different refraction indices *n*, deposited in substratum of alternated form, sometimes depositing the smaller refraction index material (n_L) sometimes depositing the one of larger index (n_H). The thickness *e* of each layer depends on the wavelength λ of the incident light in the mirror, being *e* calculated of the following way:

$$e = \frac{\lambda}{4}$$

The mirrors produced are composed by a multilayer film of aluminum (Al) and silicon dioxide (SiO_2), mounted about a glass microscope blade, and each layer of the film owns one thickness of, about, 84 nm, for the nitrogen laser in 337,1 nm. The mirror was manufactured with 10 Al's layers and 10 SiO_2's layers, resulting in a thickness of, about, 1,68μm.

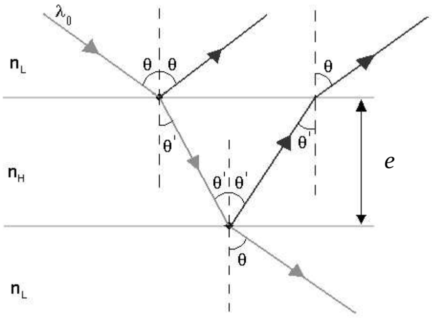

Figure 1: Rays inside multilayer

For λ= 337,1 nm, the refraction index of SiO_2 is 1,47 and for the aluminum was estimate in 0,28. The refraction index of aluminum, in the interest wavelength, was not found in the specialized literature. Your value was estimate in function of the values well-known of refraction index in other wave lengths. The obtained results were analyzed observing as the refraction index *n* and the absorption coefficient *k* vary in function of λ, as we see in the figure 2.

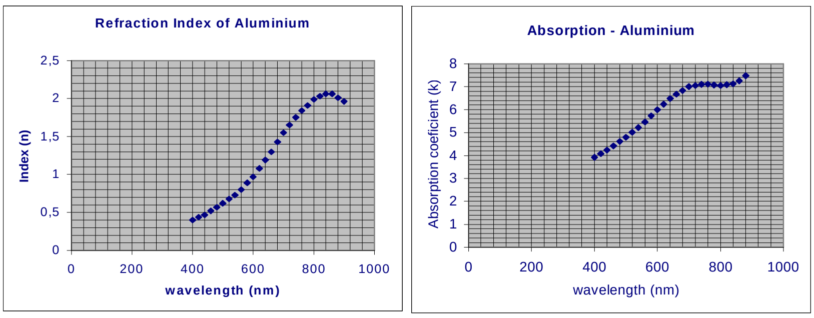

Figure 2: (A) Refraction index *n* of the aluminum in function of the wavelength of the incident light. (B) Absorption coefficient *k* of the aluminum also in function of the wavelength of the incident light.

It observes that the behavior of the refraction index of Al between λ= 400 nm and λ= 450 nm, it is very lineal, without indicating a resonance. The figure 3 shows the characteristic graph of this situation.

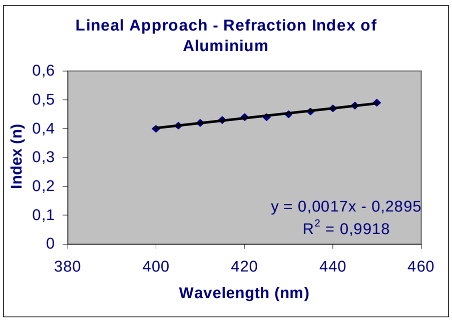

Figure 3: Lineal approach of the refraction index of Al

We obtained the following relation for the index:

$$n(\lambda) = 1{,}7\times10^{-3}\,\lambda - 2{,}89\times10^{-1}$$

The value of n_{Al} = 0,28 to λ= 337,1 nm was obtained from this equation.
The aluminum and silicon dioxide deposition in glass substratum was accomplished in a RF – Sputtering chamber. The terms for the deposition were:

- Source: 300W
- Pressure: 6,1 x 10^{-3} mBar
- Time of Exhibition: SiO_2 = 12 s and Al = 6,59 s

The thickness control is done by time of deposition, with a smaller imprecision than 1%.
The reflectivity coefficient depends, basically, of two factors: of the refraction indices of the materials that constitute them and of the number N of double - layer placed about the substratum. The reflectivity coefficient of a multilayer mirror is given by to equation

$$R = \left[\frac{\left(-\frac{n_H}{n_L}\right)^N - \left(-\frac{n_L}{n_H}\right)^N}{\left(-\frac{n_H}{n_L}\right)^N + \left(-\frac{n_L}{n_H}\right)^N} \right]^2 = \left[\frac{\left(\frac{n_H}{n_L}\right)^{2N} - 1}{\left(\frac{n_H}{n_L}\right)^{2N} + 1} \right]^2$$

where n_H is the biggest refraction index, n_L the refraction index minor and the number $2N$ is the representative value of the number of layers of the film.

Results and Discussions

The simulation shown in the figure 4 exhibition the variation of the reflectivity of the mirrors in function of the number of layers of SiO_2 or Al mounted in glass substratum. It observes that, the more layers places, larger are the probability of if reach reflectivity coefficient 1,00, in other words, 100% of reflection.

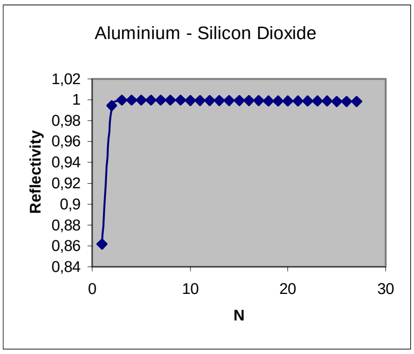

Figure 4: Simulation of the reflectivity of multilayer mirrors of SiO_2 and Al.

To compare the reflectivity of multilayer mirror constituted of SiO_2 and Al with the one of the mirror made of aluminium, used a mercury lamp as light source, a convergent lens and both kinds of mirrors, mounted in the geometry nominated in the illustration 3. A sensor *OEM Silicon Detector 35 mm²*, connected to a voltmeter, showed that when it used – if the multilayer mirror of Al – SiO_2, the intensity belonged to 540 u.a., while using the mirror made of aluminium, the intensity belonged to 267 u.a., therefore, 4 larger times.

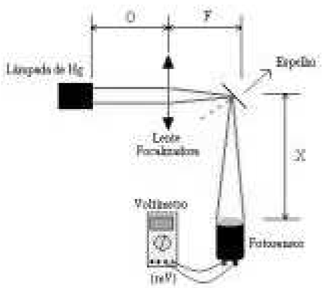

Figure 5: Setup of the experimental montage used to the acquisition of the data.

Conclusions

They like show the results, the multilayer mirrors get the upper hand about the mirrors made of aluminium. Using a mercury lamp, it observes that for reflectivity of the multilayer mirror is four larger times. Soon, when used in the nitrogen laser, in an optic cavity *etalon*, this kind of mirror will finish for increasing the gain of the laser.

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