NEW METHODS IN DEVELOPMENT OF X-RAY OPTICS FOR PLASMA DIAGNOSTICS OF LASER - PRODUCED PLASMA

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A new technology was developed for manufacturing of precise and low-cost X-ray grazing incidence microscopic optics.

CZECHOSLOVAK X-RAY MIRROR PROGRAM

Imaging experiments represent one of the main directions in the Czechoslovak X-ray astronomy program. The Space Research Department of the Astronomical Institute of the Czechoslovak Academy of Sciences in Ondřejov has been active in the development of X-ray mirrors since 1970. We have participated in 7 space X-ray imaging experiments. 6 experiments were flown onboard the Vertical 8, 9 and 11 rockets in the years 1979, 1981 and 1983 (Hudec et al. 1984a), one experiment was flown onboard the Soviet orbital station Salyut 7 in the year 1982 (Valníček et al. 1983 and Hudec et al. 1984b). The experiments represent both small solar X-ray imaging telescopes and big stellar X-ray telescope.

In the first stage (1970-1980) the grazing incidence mirrors of the Wolter 1 type were made using a technique where massive nickel replicas (wall thickness between 5 and 12 mm) were deposited onto a highly polished glass matrix, which was then removed. Although highly precise, the use of thick galvanoplastic technology was connected with the danger of damage of polished glass mandrels during the removing process due to stresses occuring during the electroplating.

After a number of tests a new technology is used since 1981 based on thin (0.1 to 0.5 mm) metallic replicas reinforced by specially filled thermoreactive plastics. This technology allows the replicas to be absolutely without stresses and thus to manufacture more copies from only one optically polished mandrel.

Since 1970, about 25 X-ray mirrors having diameters between 20 and 240 mm were made.

SOME PROBLEMS RELATED TO THE MICROSCOPIC X-RAY OPTICS

Previous experiments using X-ray imaging to investigate

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laser-produced plasma has employed pinhole cameras having poor spatial resolution (not better than 5 arcmin) and small sensitivity due to small collecting area.

The use of grazing incidence imaging X-ray mirrors represents much better possibility to get diagnostic images of laser-produced plasmas. For laboratory experiments, the most advantageous system seems to be ellipsoid-hyperboloid mirror because of finite distance of the source (Chase and Silk 1975). In recent years, there have been efforts at several laboratories aimed to the development of such X-ray microscopic optical systems (Silk 1980). Although the optics are small, the effort required to produce them was not. Usually the manufacture was performed by using conventional grinding, polishing and lapping of small inner surfaces of revolution having diameters of order of 1 cm. This is difficult and expensive - and all this results in the high cost of X-ray microscopic systems in order of US $ 100 000 (Silk 1980).

The high cost thus does not allow:

(i) the wide use of X-ray microscopic systems.

(ii) the use of cameras working with several mirrors and paths with different spectral filters simultaneously.

For these reasons, we have searched for possibility to produce small X-ray mirrors at low costs without remarkable loss of quality.

POSSIBLE SOLUTION: REPLICA MIRRORS

Our new thin-galvanoplastic and epoxy technology allows up to date to produce 5 to 10 perfect copies from only one optically polished glass mandrel. Considering that the manufacture of the master is the most costly and most laborious operation, the cost of such replicas is very low, representing only 10 to 20% of the cost of mirrors produced by classical technology. Moreover, the production usually proceeds very quickly. Although typically several months are necessary to produce one glass master, thereafter the production of each replica does not exceed several days.

Although developed for big astronomical X-ray mirrors, we have proposed to use this technology also in the field of small X-ray optics for investigation of laser-produced plasmas. Our tests show that we are able to produce numerous and low-cost mirrors this way with diameters as small as 5 mm and all this without problems(we are polishing and lapping <u>outer</u> surface).

The advantages of our mirrors are:

(i) the wide use of X-ray optics.

(ii) the possibility of production of numerous X-ray mirrors.

(iii) the possibility to built (large) arrays of identical optical systems (LAMAR in X-ray astronomy), multiple cameras with several optical paths and several spectral filters to allow more precise diagnostics (in the plasma physics).

and all this at reasonable costs.
Our X-ray microscopic program is summarized in Table 1.

TABLE 1 Czechoslovak microscopic X-ray optics program

Type +)	PP	EH
Magnificance	1x	5x
Object distance (mm)	300	150
Image distance (mm)	300	750
Grazing angle (°)	1	1
Working range (nm)	> 6	> 6
Diameter at midplane (mm)	20	17
Lenght of each surface (mm)	~25	~20
Outside diameter (mm)	28	25
Material of reflecting surface	Ni	Ni
Number of systems already produced	4	0
Number of systems to be produced in near future	4	12

+) PP = Paraboloid-Paraboloid, EH = Ellipsoid-Hyperboloid

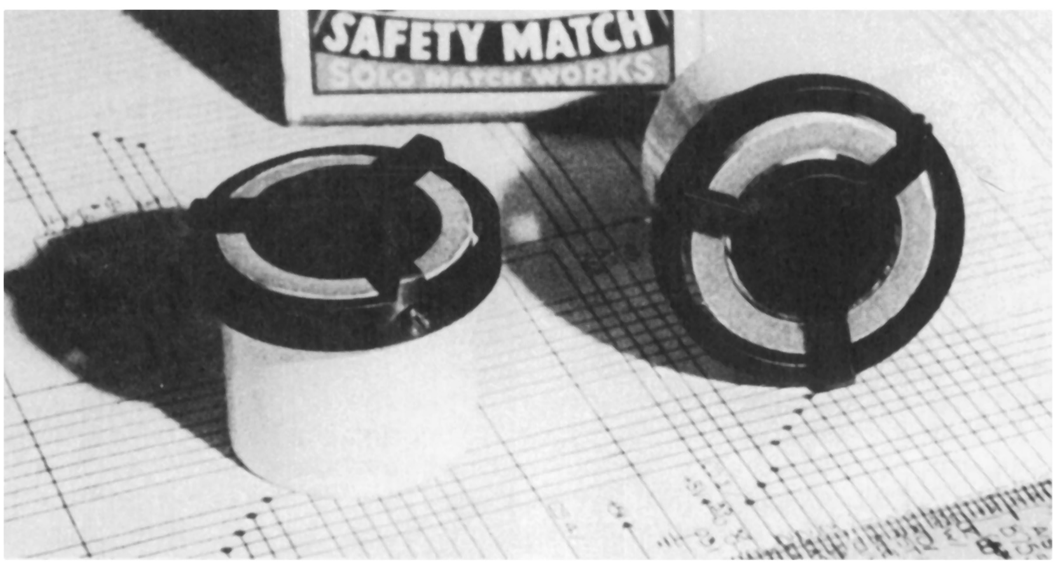

Fig. 1. Two identical paraboloidal test mirrors with 20 mm diameter removed from one glass mandrel.

First preliminary results of different tests show that the mirrors produced this way exhibit good properties and that the replica technology is well suited for applications. The replicas render a highly accurate copy of the polished glass surface as well as of the shape of the master and a

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surface finish considerably superior to that of directly polished metal can be achieved.

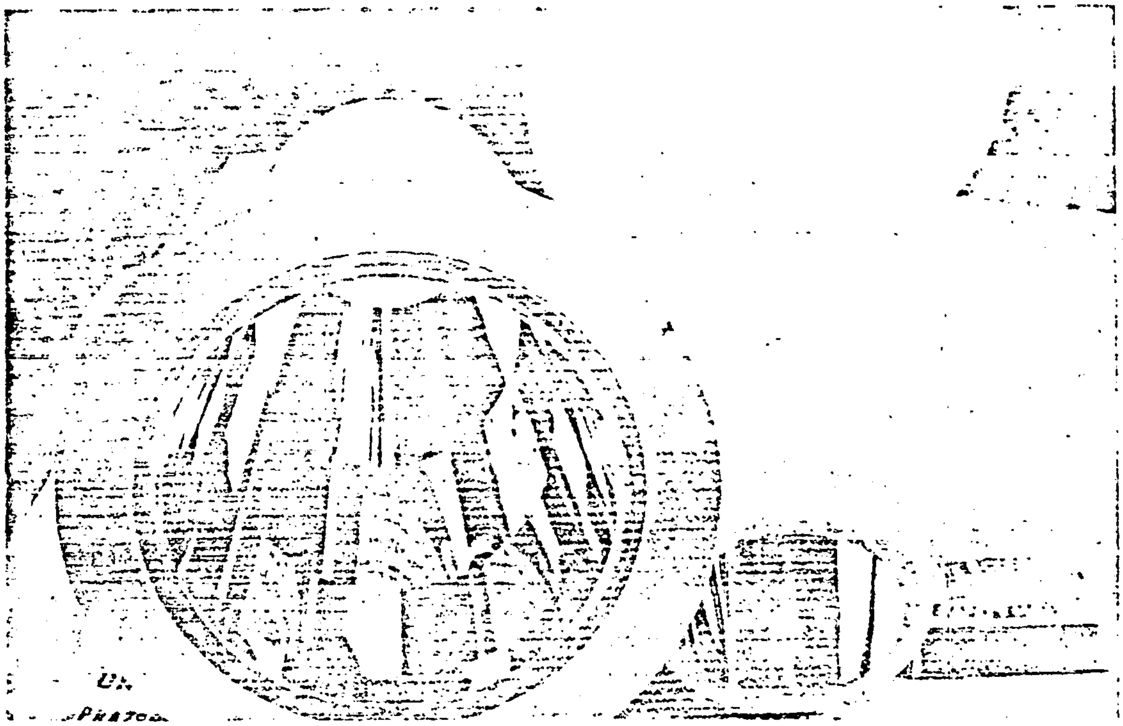

Fig. 2. Two identical hyperboloidal parts of the 130 mm inner mirror of the Salyut 7 mirror assembly removed from only one glass mandrel.

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