

# CONSTRUCTION OF LARGE FOCAL LENGTH PARABOLIC MIRRORS

## INTRODUCTION:

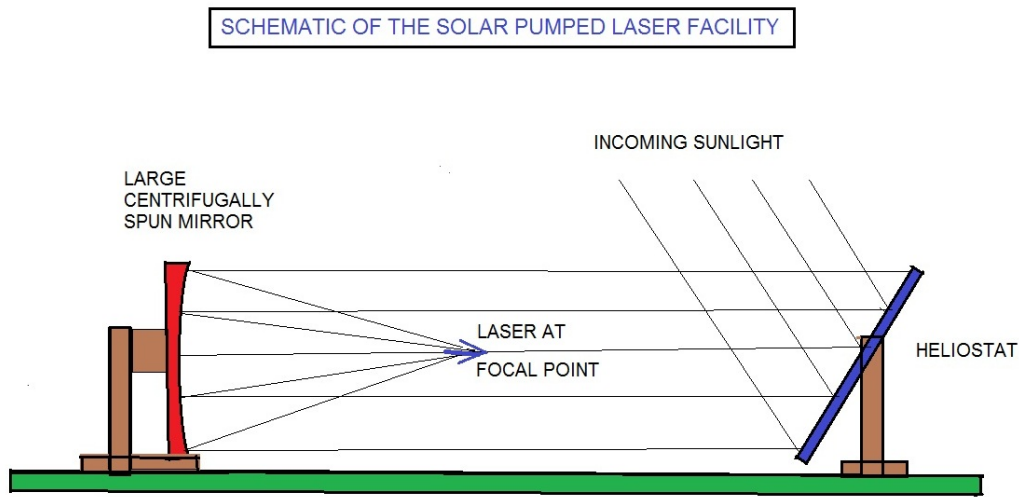
About 35 years ago I participated in a research project for NASA Langley headed by my colleague Richard Schneider from Nuclear Engineering Department here at the University of Florida. The contract was to experimentally study the lasing of a small water cooled liquid Neodymium laser confined to an annular cylinder and pumped by highly concentrated sunlight. My part of the investigation dealt with the construction of a solar facility and the fabrication of an inexpensive diameter parabolic mirror of large focal length. It is the construction of such a parabolic mirror created by centrifugal spinning which forms the main topic of this article. Further details on the overall project can be found at-

(1)- "Research on Solar Pumped liquid Lasers" by R.T.Schneider, U.H.Kurzweg, Cox,J.P, and Weinstein N.-NASDA CR-172121,(1983).

(2)- "Analysis of a 10 Megawatt Space-Based Solar Pumped Liquid Neodymium Laser System"-U.H.Kurzweg-NASA Contractor Report-3774,(1984).

## SOLAR FACILITY:

The first part of the contract work involved the design and construction of a solar facility. We decided to use a large stationary upright parabolic mirror of large focal length illuminated via a flat plate heliostat as shown-

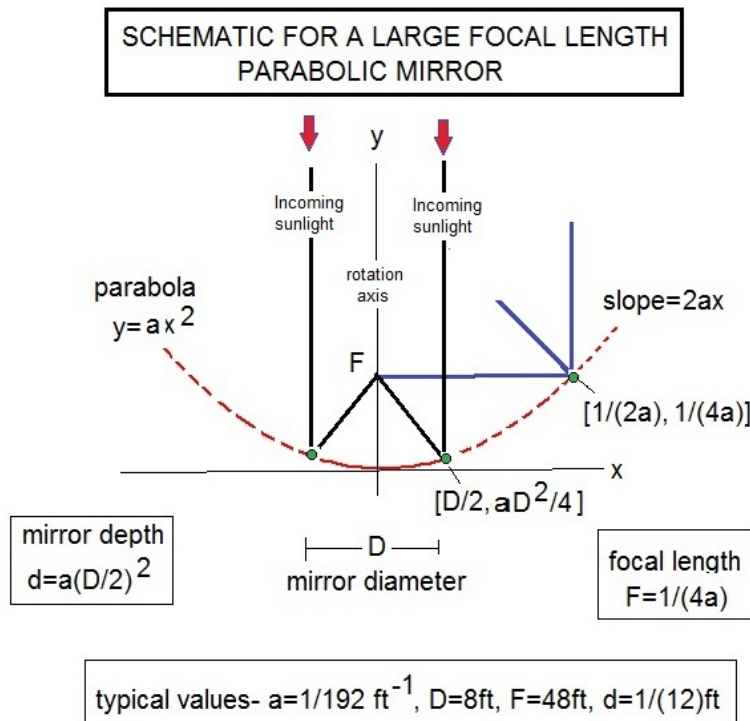


The parabolic mirror concentrated the sunlight by a factor of 100 at the focal blur circle. In turn this radiation was further intensified by using a conical axicon reflector which was sufficient to bring the solar concentration to about 1000 suns at the surface of the cylindrical laser. For a cooled liquid Neodymium laser this concentration should be sufficient to make lasing possible. Remember that at the earth's surface un-concentrated sunlight has a solar flux of approximately  $1\text{kw}/\text{m}^2$ . Hence at the cylindrical surface of the laser one can expect a solar flux of about one megawatt  $/\text{m}^2$ .

### **CONSTRUCTION OF A LARGE PARABOLIC MIRROR BY THE SPINNING METHOD:**

A major part of the NASA research project was to construct an inexpensive parabolic solar concentrator. Since for solar applications one is not required to have such a mirror to be of the optical quality needed for telescopes, we realized that one of the simplest ways to construct a large ( but not perfect) parabolic mirror was to simply spin a layer of liquid epoxy in a horizontal tray rotating at constant angular speed until it hardened into a near perfect parabolic shape. To minimize the mirror weight and the epoxy required we first carved an approximate parabolic shape into a rigid square foam pad stabilized by a frame on its back. Poring liquid epoxy onto this foam surface lying in a horizontal plain while spinning the pad at constant angular velocity for some six hours then led to a hardened parabolic surface of about a  $\frac{1}{4}$  inch thickness. This surface was next covered by strips of reflective mylar sheeting to produce the finished product. We chose a mirror of square cross-section as it was easier cut the foam pad into a large square rather than a circle. It was also easier to mount such a mirror in a vertical orientation.

The actual numbers required to form the mirror can be deduced from the following schematic-



The mirror as shown is one of diameter  $D$  and focal length  $F$ . One can also consider  $D$  to be the side length when dealing with a square cross-section mirror. The axisymmetric parabolic surface can be defined as –

$$y = ax^2 \text{ which has a derivative of } dy/dx = 2ax$$

Here ‘ $a$ ’ is a small parameter . The derivative equals 1 at  $x = 1/(2a)$ . It is at this point that the reflected ray from the extended parabolic surface passes horizontally through the focal point  $F$ . Hence the the focal point for any parabolic surface becomes-

$$F = 1/(4a)$$

Next if we think of a spinning liquid surface, its slope is  $dy/dx = x\omega^2/g$ , with  $\omega$  being the angular velocity in rad/sec about the  $y$  axis,  $g$  the acceleration of gravity (  $9.81\text{m/s}^2$  or  $32.2 \text{ft/s}^2$ ), and  $x$  the horizontal distance from the origin. Comparing this derivative with that of the mirror we find-

$$a = \frac{\omega^2}{2g} \quad \text{and} \quad F = \frac{g}{2\omega^2}$$

The depth of the mirror will be the small quantity-

$$d = \frac{aD^2}{4} = \frac{(\omega D / 2)^2}{2g}$$

This is the maximum depth to which the pre-formed foam pad must be carved.

Our mirror had the values of  $a=1/192 \text{ ft}^{-1}$ ,  $D=8\text{ft}$  and  $F=48\text{ft}$ . This produced a mirror depth of just  $d=1 \text{ inch}$ . The rotation period  $\tau$  of the rotating table had the rather large value of -

$$\tau = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{2ag}} = 10.8\text{sec}$$

to produce a  $F=48 \text{ ft}$ . focal length.

Two graduate students (Alain Kassab and another whose name I am unable to recall at the moment) were very instrumental in bringing this part of the project to successful fruition. They received their PhD degrees from the University of Florida in the late 80s with Dr. Kassab going on to become a full professor at the University of Central Florida. A lost photo of one of them holding a smoking and burning two by four held at the primary focal point of the mirror was quite spectacular during a demonstration of our solar facility for some local newspaper reporters (shades of Archimedes at the siege of Syracuse in 212BC).

## CONCLUSION:

We were able to show that parabolic mirrors of large focal length can be constructed by spinning a preformed surface about a vertical axis at constant rotation rate while the liquid epoxy was pored onto the rotating surface and allowed to harden. The resultant rigid parabolic surface was then coated with a thin layer of reflective mylar strips to complete the mirror. With aid of a secondary axicon collector we were able to achieve the desired 1000 sun concentration required for laser action. Although I have not worked again in solar energy since the 1980s, several of my related works on axicon concentrators and convection along inclined surfaces such as encountered in solar water heaters have become recognized by the solar community. In 1984 NASA awarded me a Certificate of Recognition for the "Fabrication of Large Focal Length Parabolic Mirrors".

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