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A viewpoint on moderate size solar telescope

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Abstract. In this paper an overview of solar optical instrumentation is presented. Some discussion on the salient problems in solar physics is also given, which should be kept in mind for planning and designing of required telescope and backend instruments. This paper discusses future programs and instrumentation in view of possible Indian contribution to Solar Physics.

1. Introduction

One of the important objectives of the solar observational program is to study the finest possible details on the Sun. To achieve this objective solar astronomers have tried all kinds of innovations e.g., putting telescopes on high towers, mountain peaks, in the middle of large lakes, flying them in balloons, or in spacecrafts. In this respect, the solar astronomers are severely handicapped as compared to their stellar counter parts because soon after sun rise, the solar radiation heats up the atmosphere and the ground, which in turn creates convection and turbulence in the air and thus spoils the "seeing" or the image quality. For a stellar astronomer 1 arc second or better seeing conditions may not be so unusual an event, but for solar work 1 arc sec moments are rather wide apart and rare. An interesting review article has been written by Zirin (1992), describing some of the important aspects of solar instrumentation.

2. Telescope site for solar optical observations

Mountain site: The earlier concept of putting solar observatories on high mountain peaks is slowly changing. The mountains get heated soon after sunrise (say within 1 or 2 hours) and develop convection currents, rising along the mountain slopes. Generally, mountain sites are not the best places to yield long stretch of arc second solar seeing conditions. For example, at Mount Wilson, Kitt Peak, Sac Peak and Pic du Midi observatories, short spells of very good seeing have been obtained but only for very limited period and very rarely. At La Palma and Tenerife Islands off western African coast in the Atlantic, moments of exceptionally very good seeing (0" .5 arc or better) have been observed.

Lake site: A large body of water around a solar observing site provides exceptionally good seeing.

From the experience gained at the Big Bear lake, San Fernando lake and Fatehsagar lake at Udaipur, it is now well established that lake sites yield on an average good to very good seeing, of the order of 1" to 1" .5 arc for long period of time, say 5 - 6 hours per day. There could be moments when seeing may be better than 1" arc. From the experience of lake sites, several new solar observatories are being planned near large body of water, e.g., the Huairou solar station, near Bejing. However, it may be mentioned that it will depend on the specific program, whether one needs consistent long period of average good seeing or occasional short moments of very good seeing of say fraction of second of arc.

3. Building, dome and telescope design

Building : Telescope building plays an important role in creating local turbulent thermal environment. Large monolithic building absorbs solar energy which has big thermal capacity. The absorbed heat is radiated around the telescope and strong thermal currents are created. To counteract this effect the Kitt Peak's McMath - Pierce Solar telescope building has glycol coolant pipes running around the outer shell of the building, however, the coolant arrangement had never been used, Livingston (1995) reports that they are going to put it in use. To minimize the heating of the building, it is essential to design an optimum minimum sized building, so that heat absorption and re-emission be minimum.

Dome: The effect of telescope dome on local seeing has been well recognized. The heat generated in the dome gushes through the slit opening, just in front of the telescope objective. To avoid this, Keipenhuer designed a domeless solar telescope at Capri, and other telescopes are the McMath - Pierce solar telescope at Kitt Peak, the high resolution telescope at Pic du Midi with the objective lens protruding out of the dome, the San Fernando observatory's retractable dome, the Sac Peak's vacuum tower telescope, the Huairou observatory's movable dome. Although, domeless telescopes do have some disadvantages, such as the windshake of telescope etc. At the Udaipur Solar observatory, we realize that the solar seeing was far better when we had the telescope in a roll - off roof, as compared to a conventional telescope dome, even though the observatory is on an island. Great care has to be taken to design proper telescope 'shelter' to take into account the 'dome generated seeing'.

Telescope's internal seeing : The biggest contributor to the local bad "seeing" is the telescope's internal thermal convection currents, caused by temperature gradients along the length of the telescope tube. The concept of evacuating the telescope to a level of 10^{-3} or 10^{-4} mm is one of the standard techniques now being used and have been found to work satisfactorily to some limited extent. Several new vacuum solar telescopes have been built for high resolution observations. The limitation of vacuum solar telescope is due to the quality of the optical window, to withstand the desired low pressure and maintain the figure etc., further the window restricts observations in far infrared region of the spectrum. A few year ago, the idea of using helium gas at relatively higher pressure (10^{-2} mm) has been mooted by Livingston. A few trial runs have shown that considerable improvement in seeing can be achieved by helium. However, nowhere in the world helium is being used in any solar telescope, at present.

4. Thermally invisible solar telescope

A new concept is being suggested by Livingston (1995) of "Thermally Invisible Telescope". The idea is to have a solar telescope in complete thermal equilibrium with it's surrounding free air. In principle, if the thermal equilibrium could be maintained inside the telescope tube and the outside air, thus a thermally homogeneous air column will result along the optical path. In such a system, the image quality would then be limited only by site conditions and the overlying atmosphere. In case of fuse quartz and ceramic mirrors, the aluminium reflective coating absorbs about 10% of the incident radiation. Thermal conductivity of SiO_2 being low, the outer layer heats up quickly. Experimental evidence shows that the onset of "mirror seeing" occurs for a 1° C, mirror-air temperature difference. It's relative importance depends on the magnitude of other image aberrations such as surface irregularity, astigmatism and external atmospheric seeing. To get some idea for mirror substrates in Table 1 are given the properties of some materials in view of their stiffness, conductivity, and coefficient of thermal expansion.

Table 1. Properties of mirror substances

Material parameters	Be	Sic	Al	SiO_2
Stiffness $E/\gamma\,(10^6 m)$	15.1	13	2.7	3.2
Conductivity λ (W/mK)	159	185	220	1.38
CTE $\alpha(10^{-6} K^{-1})$	11.4	2.5	23.9	0.55

It will be noticed that SiC (silicon carbide) having a thermal conductivity of 185 W/mK and coefficient of thermal expansion of only 2.5 could be an ideal material for making substrates. Thus with the use of SiC mirrors, the heat absorbed by the mirrors could be quickly flushed out of the telescope tube and no heat will accumulate near or in the mirror. Lens objectives are used but they have several inherent limitations for moderate big aperture telescopes.

5. Essential auxiliary instruments for solar telescopes

While planning solar telescopes great effort is put in designing the optics, its aperture, mounting, optical layout etc., but many a time extremely essential auxiliary equipments are either missed or neglected, some of them are mentioned below:

- Solar image guider,
- Active mirror "tip - tilt" guider on main beam,
- Correlation traker or preferably adoptive optics,
- Extremely rigid HA and Dec or alt-azimuth mounting,
- Avoidance of heating of all non-optical surfaces, exposed to sun light.

6. Scientific objectives for a solar telescope

The concept for a general purpose solar telescope is slowly shifting to specific problem oriented instruments, for example the recent thrust on helioseismology - very specialized telescope-instruments have been designed and are operational to carry out only one specific task.

In Indian scenario it may be still useful to think and plan for more or less a general purpose moderate to a large size solar telescope. Some of the major scientific problems in observational solar physics (not including coronal studies) are as follows:

- Vector magnetic and velocity solar field structure,
- Solar activity in all it's form,
- Sub arc second solar phenomena,
- IR studies upto 20 microns or so.

It is indeed very difficult to define what is a "moderate size telescope" for solar work. The existing solar telescope aperture range from 1.5 meters to a few centimeters (e.g., 6.5 cm GONG telescope). However, one may still consider an aperture of about 60 cm as rather a moderate size solar telescope. Generally, for solar observations large aperture may not be required in view of the large photon flux, but the need for large (even upto 2-3 meters) apertures is being talked about, for high spectral, spatial and time resolution and IR studies.

Instrumental polarization: This is a very serious lacuna in solar telescopes, which needs to be eliminated or minimized. Several ideas for symmetrical optical layouts have been put forward. A very exhaustive study had been done in connection with the LEST project.

Spectral studies: Wide coverage in wavelength along with high spectral dispersion is required for most of the solar problems. To combine many requirements, lately Fourier Transform Spectrometer (FTS), high dispersion Littrow and collimator-camera spectrographs have been designed and are in use.

Two-dimensional monochromatic observations: Since the invention of Lyot birefringent filter, this instrument has found extremely wide application in solar astronomy. Filters of pass band as narrow as 0.05 Å have been built. Several different versions using birefringent elements, Fabry-Perot or Michelson interferometer and magneto-optics resonance filters are being extensively used for monochromatic solar observations. Each of these instruments have merits and demerits, depending on the specific problem, one makes the choice of the instrument to be used.

References

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