SCO4 SolTrace

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1 Introduction

In an attempt to study the optical behaviour of the SCO4 system and validate COMSOL's results, SolTrace software was revisited. Previous attempts with the software for SCO1, SCO2 and SCO3 were not successful, due to a software bug in deep parabolic shapes.

SolTrace does not include automatic tracker modules, so each mirror's aiming point has to be set manually. An equation was developed in order to calculate each mirror's aiming point so that the reflected rays hit the absorber.

2 Mirrors arrangement

Flat 18.7x14mm mirrors were used for the test case using the geometry settings shown in figure 1.

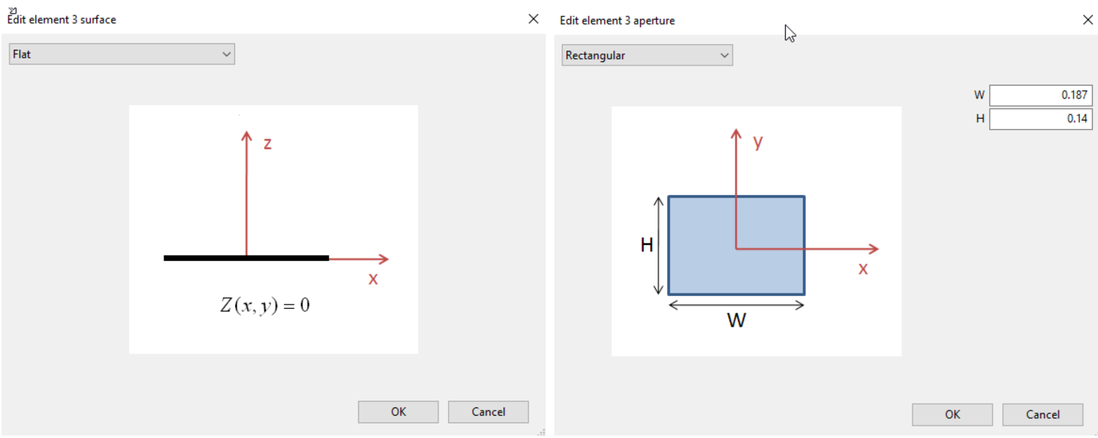

Figure 1: Surface and aperture settings in Geometry tab

The longest dimension of the mirror facet is set at the x axis (labelled W in figure 1) so that the longest dimension of the mirror array lies on x axis. The resulting arrangement is that of 2. The concentrating system does not have a built-in axis, so as a convention, the axis of the longest dimension is considered the longitudinal one and the shortest one the transversal one as indicated in figure 2.

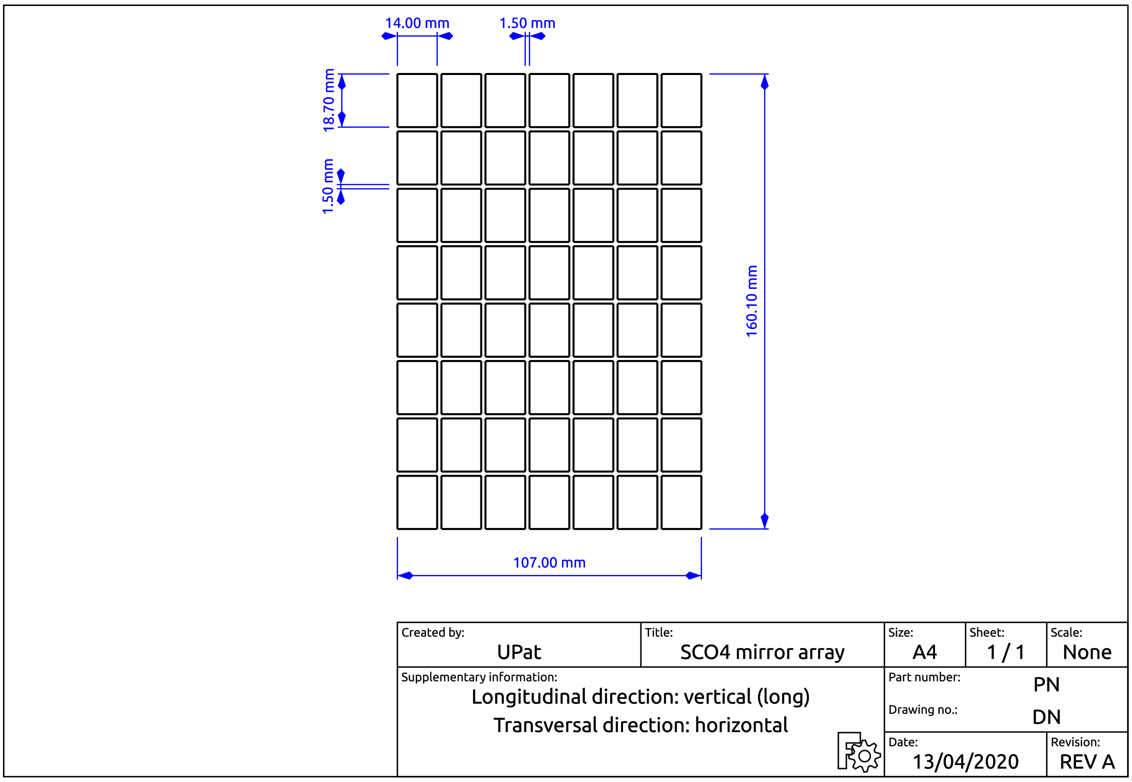

Figure 2: Mirror array

3 Aim point calculation

The mirror array center is set at $(0, 0)$ and the absorber is set $1.5m$ above the array center, at $z_a = (0, 0, 1.5)$. The 3-dimensional coordinates for each surface created in SolTrace correspond to the surface center. The aiming point of each facet is defined using the facet's normal vector. The $x - z$ plane of the setup is shown in figure 3, where O is SolTrace's reference point $(0, 0)$, S represents the sun, A the absorber, DE the mirror facet with middle M and P the facet's aiming point. The solar elevation angle α for solar noon is shown in figure 3 ($\alpha = 90°$). The goal is to create a function that gets the solar zenith angle θ_z and the distance l of the mirror from $(0, 0)$ and returns the aimpoint on the z axis z_p

Let $OM = l$ and $OP = z_p$, then:

$$z_p = l \tan(\phi + \omega) \tag{1}$$

MP is the angle bisector of SAM, so:

$$\phi + 2\omega + \alpha = 180° \tag{2}$$

$$\omega = \frac{180° - \alpha + \phi}{2} \tag{3}$$

Replacing (3) in (1) we get

$$z_p = l \tan\left(\phi + \frac{180° - \alpha + \phi}{2}\right)$$

Expressing ϕ using known lengths we get $\phi = \arctan \frac{z_a}{l}$, so:

$$z_p = l \tan\left(\frac{180° - \alpha + \arctan \frac{z_a}{l}}{2}\right)$$

α is the solar elevation angle, so replacing $\alpha = 90° - \theta_z$ we get:

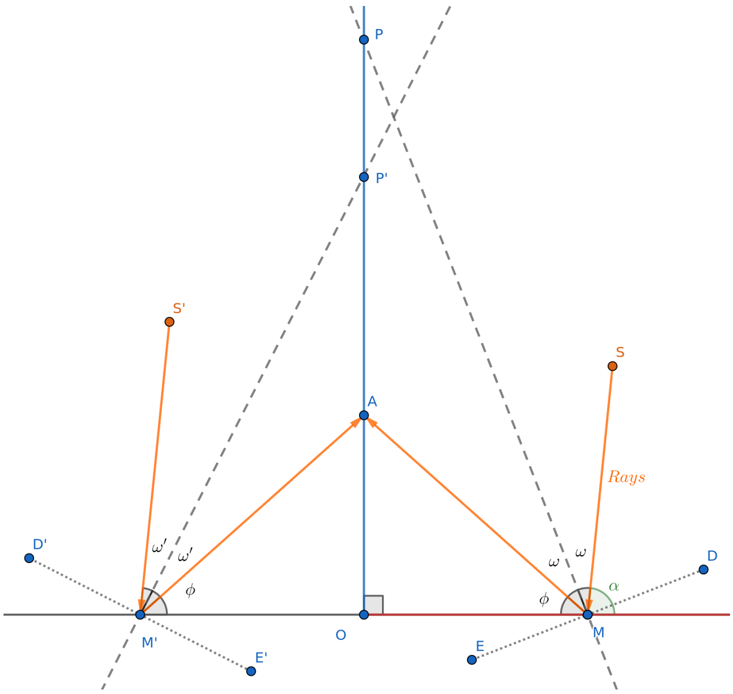

Figure 3: Mirror facet aiming point

$$z_p = l \tan\left(\frac{90^\circ + \theta_z + \arctan\frac{z_a}{l}}{2}\right) \tag{4}$$

Considering angle ω' for the mirror M', we get:

$$\phi + 2\omega' = \alpha$$

$$\phi = \alpha - 2\omega'$$

Using the same methodology, equation (4) becomes:

$$z_p' = |l| \tan\left(\frac{90^\circ - \theta_z + \arctan\frac{z_a}{|l|}}{2}\right) \tag{5}$$

Equations (4) and (5) are summarized as:

$$z_p = \begin{cases} l \tan\left(\frac{90^\circ + \theta_z + \arctan\frac{z_a}{l}}{2}\right) & l > 0 \\ |l| \tan\left(\frac{90^\circ - \theta_z + \arctan\frac{z_a}{|l|}}{2}\right) & l < 0 \\ 1 & l = 0 \end{cases} \tag{6}$$

If a mirror center is at $l = 0$, z_p can be set an any arbitrary number in SolTrace eg. 1. The function described above works for $-45^\circ < \alpha < 45^\circ$.