SCO4 SolTrace

Orestis Panagopoulos

September 2020

In an attempt to study the optical behavior of the SCO4 system and validate the results obtained using the COMSOL software, the SolTrace software was used.

SolTrace does not include automatic tracker modules, so the aiming point of each mirror has to be set manually. For this purpose we developed an equation that calculates the aiming point of each mirror so that the reflected rays impinge on the absorber. The following section describes the methodology used to develop this equation.

An LK script [1] was developed to calculate the mirror positions and aim points. The ray-tracing parameters can be also set from within this script. To use the script, launch SolTrace, open the **automation.lk** script and run it. The script uses **empty.stinput** as input. It is an empty SolTrace project which does not have to be saved.

1 Aim point calculation

The mirror array center is set at point $(0, 0)$; the absorber is set at $1.5\,m$ above the array center, at $z_a = (0, 0, 1.5)$. The 3-dimensional coordinates for each surface created in SolTrace correspond to the center of the surface. The aiming point of each facet is defined by means of its normal vector. The $x - z$ plane of the setup is shown in figure 1, where O is the reference point $(0, 0)$ of SolTrace, S is the position of the Sun, A the absorber, DE the mirror facet with M its mid-point and P the facet's aiming point. The goal is to develop an equation that calculates the aiming point on the z axis z_p as a function of the solar zenith angle θ_z and of the distance l of the mirror from point $(0, 0)$.

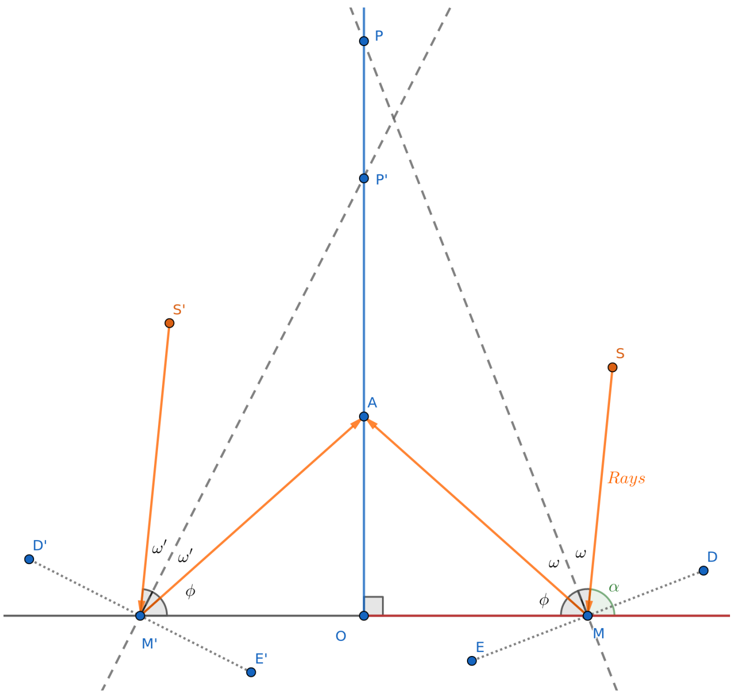

Figure 1: Mirror facet aiming point

Let $OA = \alpha$, $OM = l$ and $OP = z_p$, then:

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

MP is the bisector of angle SAM, so:

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

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

Replacing (3) in (1) we get

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

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

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

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

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

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

$$\phi + 2\omega' = \alpha \Rightarrow \omega' = \frac{\alpha - \phi}{2}$$

Using the same methodology, equation (4) becomes:

$$z'_p = |l|\tan\left(\frac{90° - \theta_z + \arctan\left(\frac{z_a}{|l|}\right)}{2}\right) \tag{5}$$

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

$$z_p(\theta_z, l) = \begin{cases} l\tan\left(\frac{90° + \theta_z + \arctan\left(\frac{z_a}{l}\right)}{2}\right) & l > 0 \\ |l|\tan\left(\frac{90° - \theta_z + \arctan\left(\frac{z_a}{|l|}\right)}{2}\right) & l < 0 \\ 10 & l = 0 \end{cases} \tag{6}$$

If a mirror center is located at $l = 0$, the z_p parameter can be set in SolTrace at any arbitrary number, e.g. 10. The function described above is valid for solar elevation angles within the range $-45° < \alpha < 45°$.

References

[1] *LK Scripting Language, Version 00*. Jan. 2016. URL: `https://www.osti.gov//servlets/purl/1374804`.