THE GLASS SUNDIAL

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HELIOS SUNDIALS EK
Owner: Dr.-Ing. Carlo Heller
Begasweg 3
65195 Wiesbaden
Germany
Phone: +49 - 611 - 185 11 06
Email: carloheller@helios-sonnenuhren.de

The glass sundial uses a glass cylinder that focuses the sunlight in the shape of a sharp arrow (caustic). The tip of the arrow shows the time on a helical dial. The daily movement of the sun from east to west causes the light arrow to rise high to the sky.

The equatorial sundial can be used with a right-turning helix in the northern hemisphere and with a left-turning helix in the southern hemisphere.

The great advantage of the helix is that it never gets in the way of the sun's rays. This means that it shows the time all day and all year round, even at sunrise and sunset and at the equinoxes. This is an advantage over normal equatorial sundials.

To set up the sundial, simply set the latitude and point it north using the compass.

The sundial mirrors the natural path of the sun. When the sun reaches its daily peak in the south, ascending steadily after its morning rise, it is true noon and the sundial shows 12 noon solar time. This midday divides the day into two halves of equal length in the true sense of the word, and it now takes the same amount of time for the sun to set again in the evening.

Two solutions are presented that have already been finished as prototypes. The attached video shows the function of the time display with the sun.

Model 1 with light arrow and radial helix

In this construction, the helix is arranged radially, i.e. perpendicular to the glass cylinder. The diffusing glass allows the arrow light up in full size and the time can always be easily read.

The prototype shown in the picture was made of brass investment casting using 3D printed wax models. The height of the sundial is 130 mm, the diameter of the glass cylinder is 25 mm, that of the helix is 40 mm.

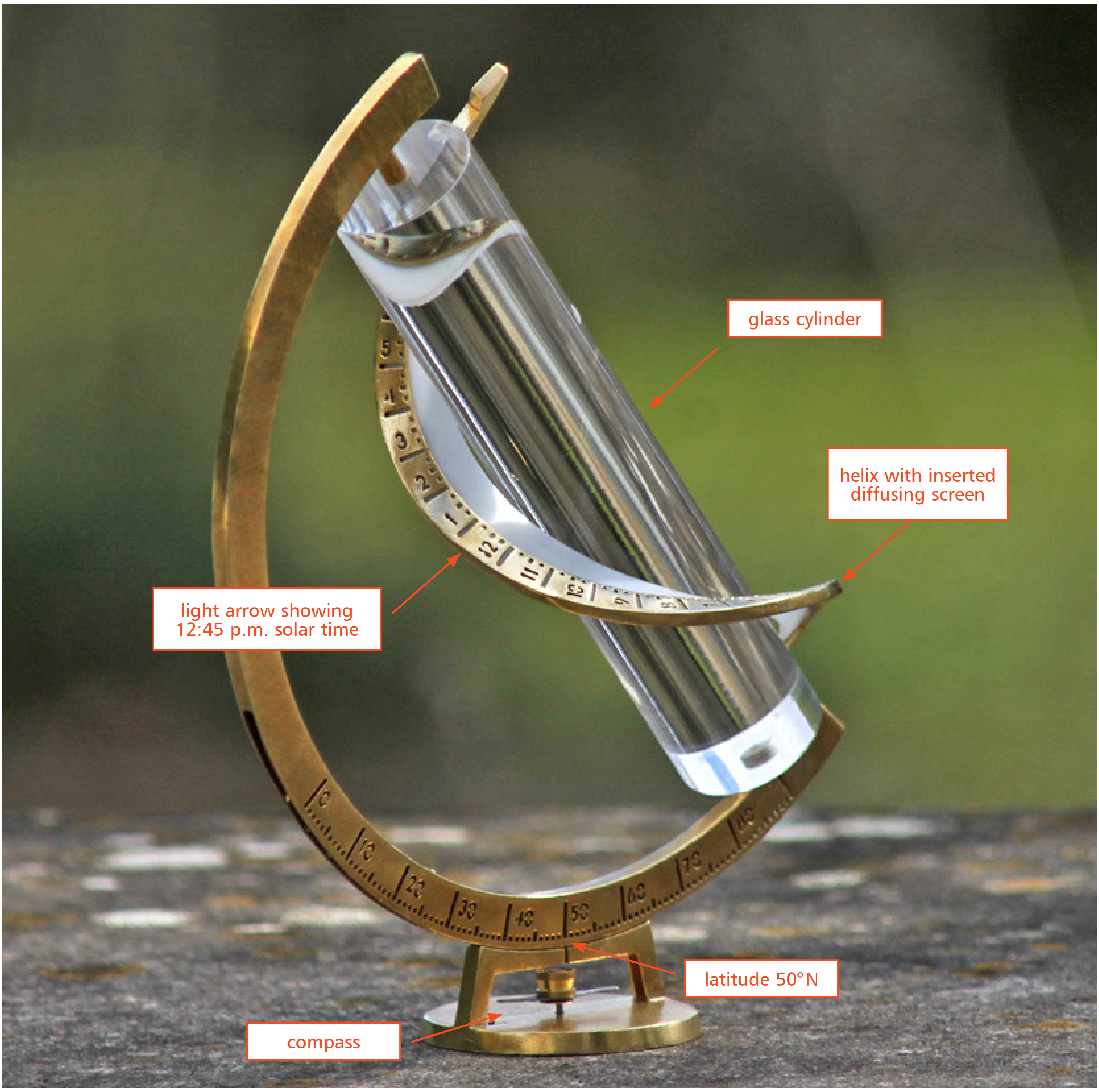

Fig. 1: Model 1 with light arrow and radial helix

Model 2 with light line and axial helix

In this model, a glass tube is placed around the glass cylinder. The surface of the glass tube is exactly in the focal plane of the light focused by the glass cylinder. This results in a fine line of light that is used to indicate the time.

The time scale is wound around the glass cylinder as an axis-parallel helix. The light line is very clearly visible and the construction is elegant and simple.

The disadvantage, however, is that the light bar passes under the cylinder at midday, so you have to look from below to read the time.

To solve this problem, you could arrange a mirror in such a way that you can comfortably read the time from above. Vertically arranged Roman numerals allow the time to be read the right way around in the mirror.

Another possibility is to place the time scale not on the diffusing surface, but on a separate radial metallic helix (similar as in model 1).

The glass cylinder of the model 2 has a diameter of 50 mm, the glass tube 70 mm. Other diameters can be used, but they must always be in a certain proportion. In the model, diffusing foils were used, but you can get a better quality by etching the diffusing surface.

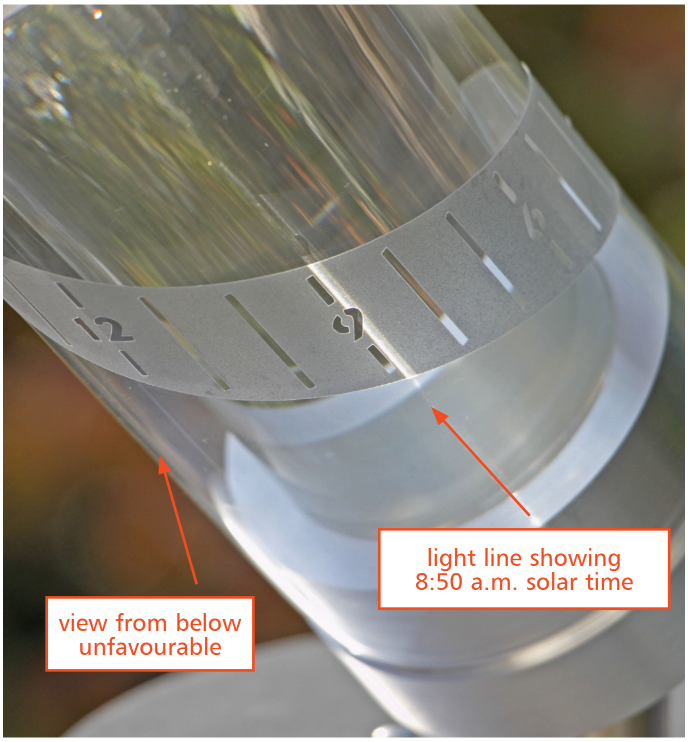

Fig. 2: Model 2 with light line and axial helix

Fig. 3: Inside the glass tube is the cylindrical lens (D=50mm).

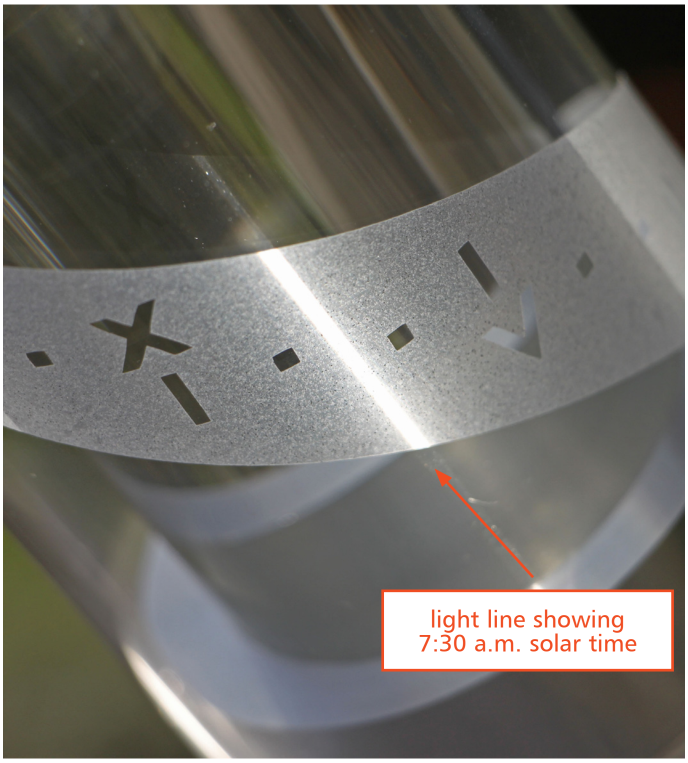

Fig. 4: Model 2 with vertical Roman numerals

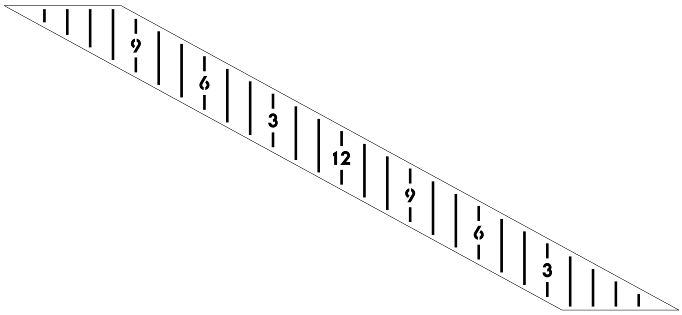

Fig. 5: Time scale with Arabic numerals

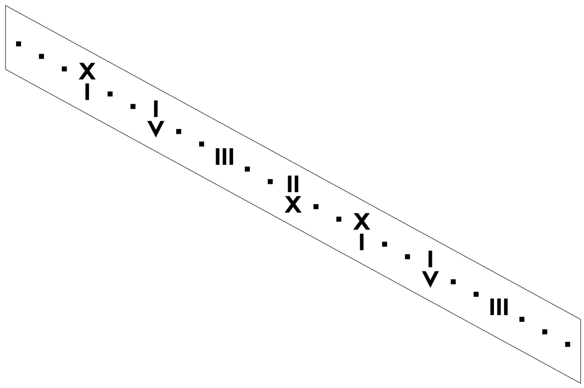

Fig. 6: Time scale with vertical Roman numerals (axisym.)

Fig. 7: Different diameters of the glass cylinders produce light arrows with different focal lengths.

Fig. 8: The light arrow from model 1

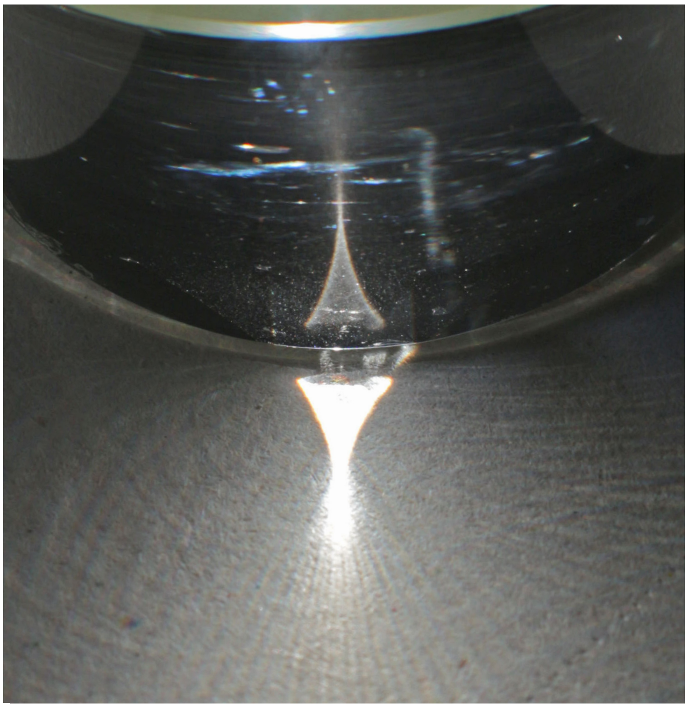

Fig. 9: The light arrow from model 2 (without the glass tube)

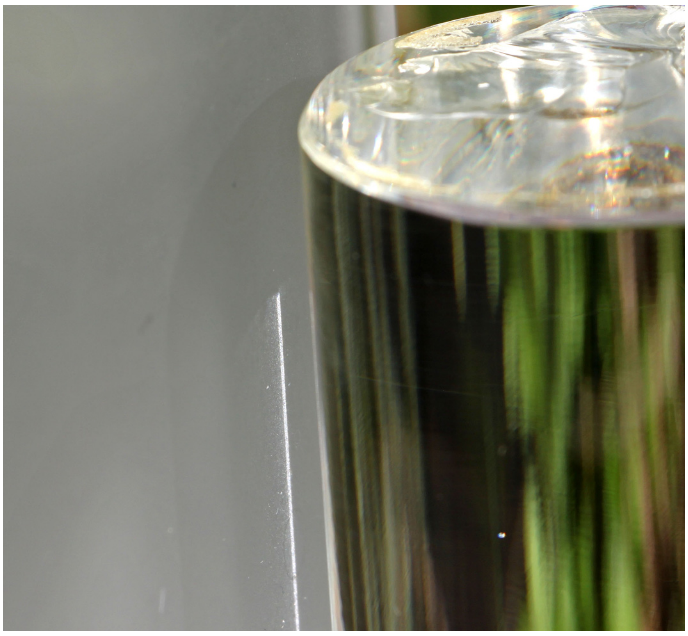

Fig. 10: The projection of a fine line of light onto etched glass

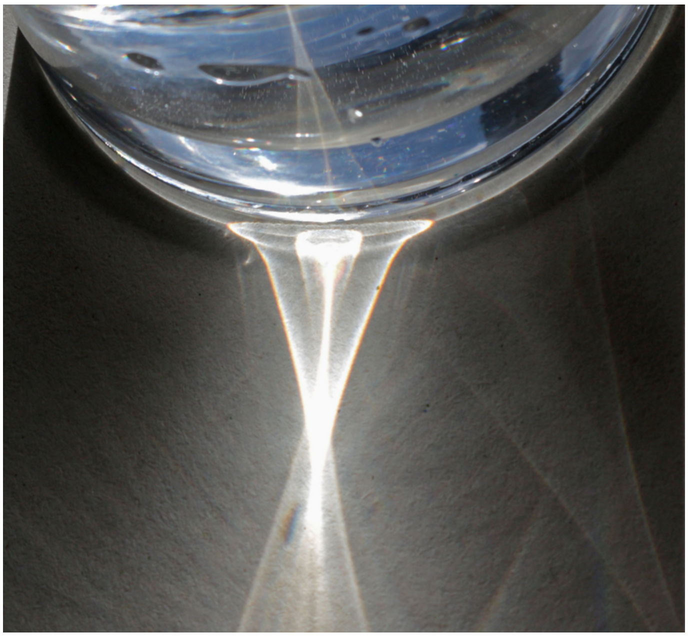

Fig. 11: To try out for yourself: a drinking glass filled with water

Model 3 with light line and axial helix without outer tube.

An attractive variant of model 2 is the version without the outer tube. This is omitted if a glass with a refractive index of n=2 or approximately n=2 is used for the glass cylinder.

Then the focal plane is on the surface of the cylinder, so that it is possible to make the light line visible there. The helix can then be applied directly to the cylinder lens. The outer tube is no longer needed.

Figure 11 first shows the beam path of model 2. Here, the glass cylinder has a refractive index of n = 1.5725, so the focus is s = 9.3 mm away from the exit surface. Therefore, the light is collected on an outer tube.

Schott Glass offers a heavy flint glass with the name N-LASF 55. The dispersion of the glass is quite high, i.e. the refractive index in the visible range of the light is clearly dependent on the wavelength. In figures 12, 13 and 14, the ray paths of the colours red, green and blue can be seen. It can be assumed that the light line will show the rainbow colours as a result. Possibly a beautiful effect.

Another advantage of model 3 is that the glass cylinder acts like a magnifying glass, so that you can read the time magnified through the glass. This would possibly solve the problem of the light line passing under the glass cylinder at noon, because you can then read the time comfortably from above. However, the numbers are reversed. Therefore, the use of a symmetrical character set (Fig. 6) would be favourable.

Schott N-BAK1
n = 1.5725(587.6nm)
d = 50.0mm
s = 9.3mm

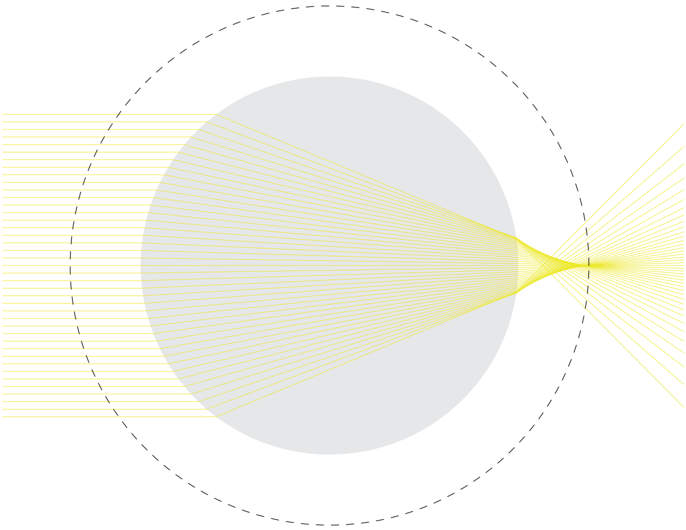

Fig. 11: beam path of model 2

Schott N-LASF 55
n = 1.96118(546.1nm)
d = 50.0mm
s = 0.5mm

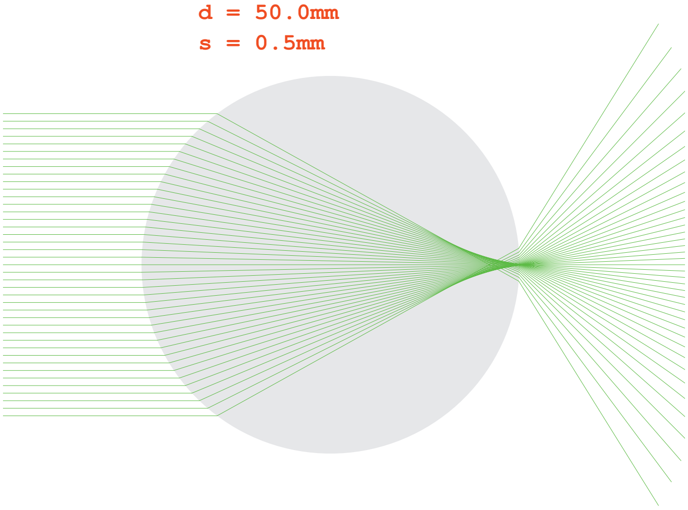

Fig. 13: beam path of model 3 (green light)

Schott N-LASF 55
n = 1.94473(656.3nm)
d = 50.0mm
s = 0.7mm

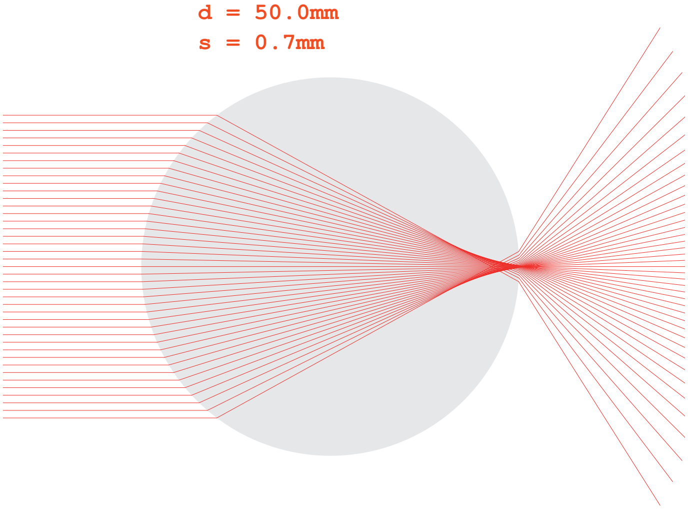

Fig. 12: beam path of model 3 (red light)

Schott N-LASF 55
n = 1.99454(435.8nm)
d = 50.0mm
s = 0.1mm

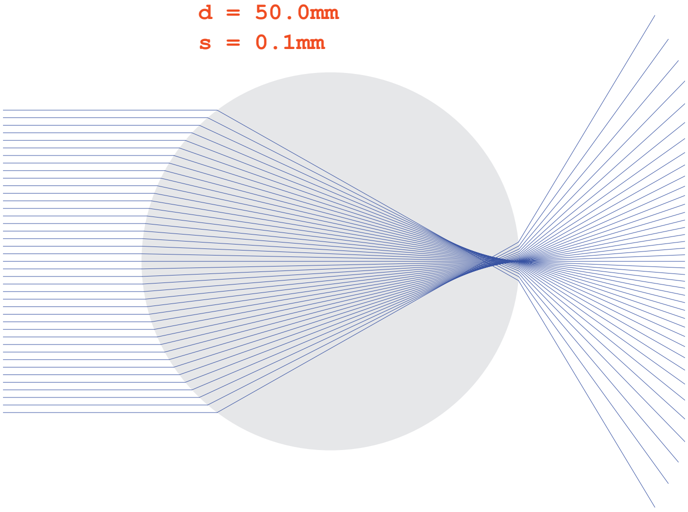

Fig. 14: beam path of model 3 (blue light)

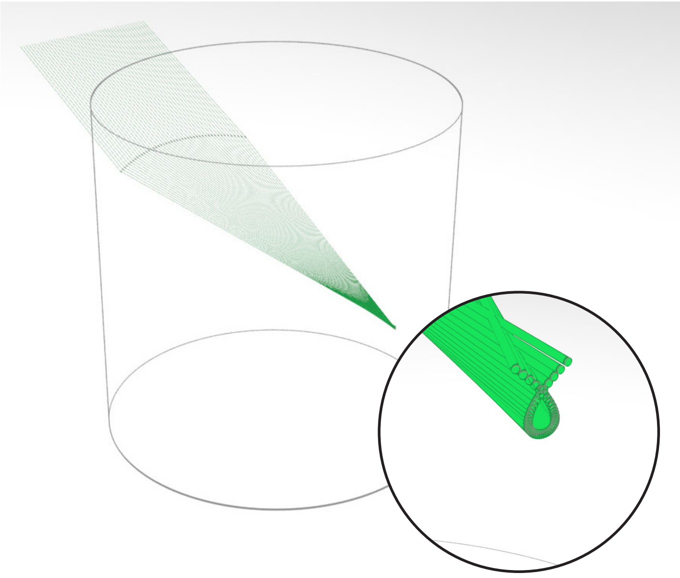

Fig. 15: Summer solstice beam path (solar declination 23.44°)

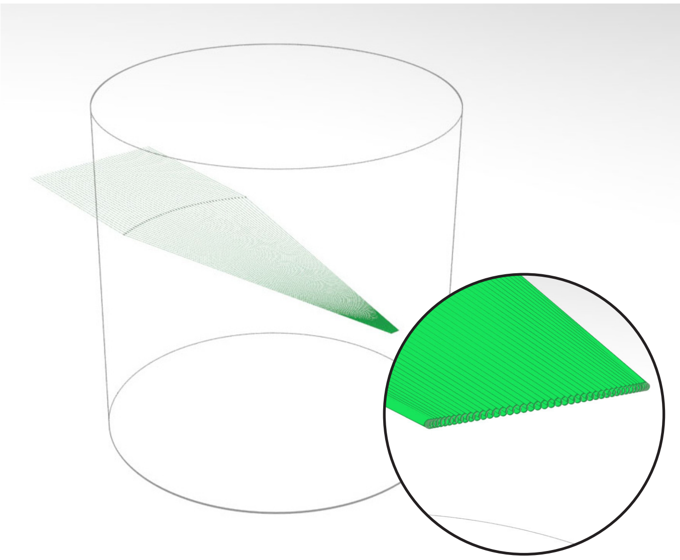

Fig. 16: Equinox beam path (solar declination 0°)

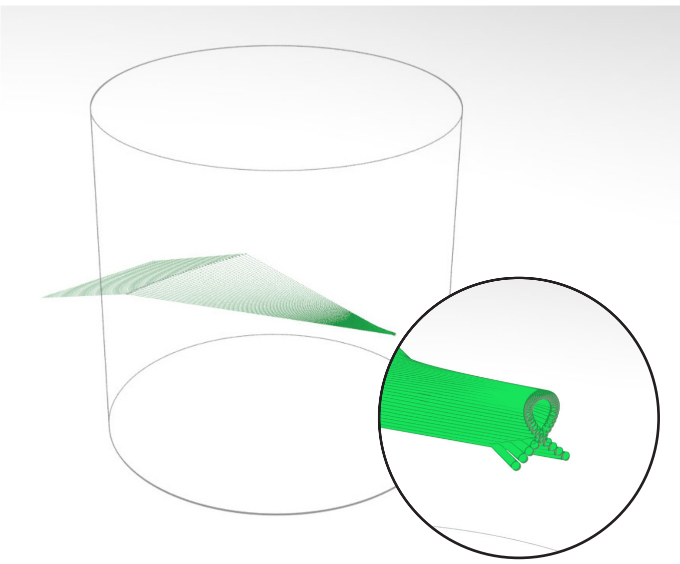

Fig. 17: Winter solstice beam path (solar declination -23.44°)

The light line at different times of the year

The appearance and width of the light line depends on the season and the refractive index of the glass. Preference is given to a glass that has the narrowest possible light line during the sundial's main period of use.

The Schott glass N-LASF 41 with a refractive index of n=1.82923 (656.3 nm) was selected. Fig. 15 to 17 show the beam path at the solstices and the equinoxes. The formation of the image on the cylinder surface is shown enlarged.

Fig. 18 shows the width of the light line as a function of the solar declination. The width is smallest at the solstices (0.36 mm) and largest at the equinoxes (2.75 mm).

In comparison, the N-LASF 55 with n=1.94473 (656.3 nm) in Fig. 19 has the greatest width at the solstices (3.1 mm) and the smallest at the equinoxes (0.51 mm). The higher dispersion is also a disadvantage.

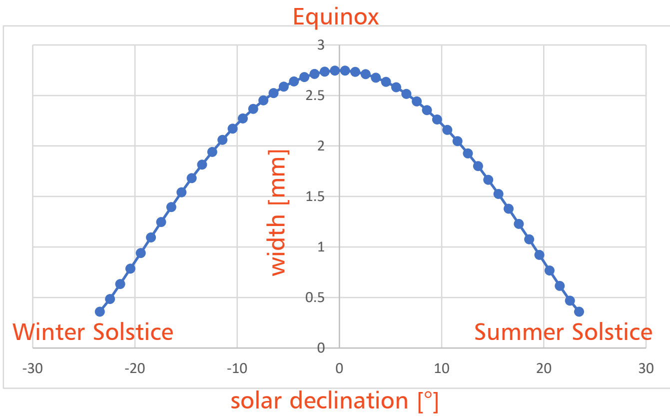

Fig. 18: Width of the light line as a function of solar declination with Schott Glas N-LASF 41

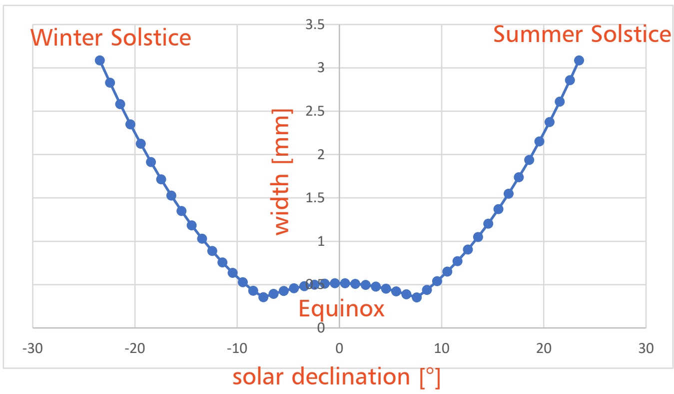

Fig. 19: Width of the light line as a function of solar declination with Schott Glas N-LASF 55

Model 4 with axial helix for the light line and radial helix for the time scale.

Fig. 20 shows the glass sundial at the summer solstice (20th June) at 9:30 solar time (LAT) at latitude 50°N.

The sundial is adjustable for latitudes from 0° N to 70° N. A left-hand helix is required for the southern hemisphere.

The radial helix for the time scale is necessary to be able to read the time comfortably. The diameter of the glass cylinder is 100 mm, the height is 200 mm. However, it is possible to choose smaller.

Fig. 21: Detail at 3 o'clock pm

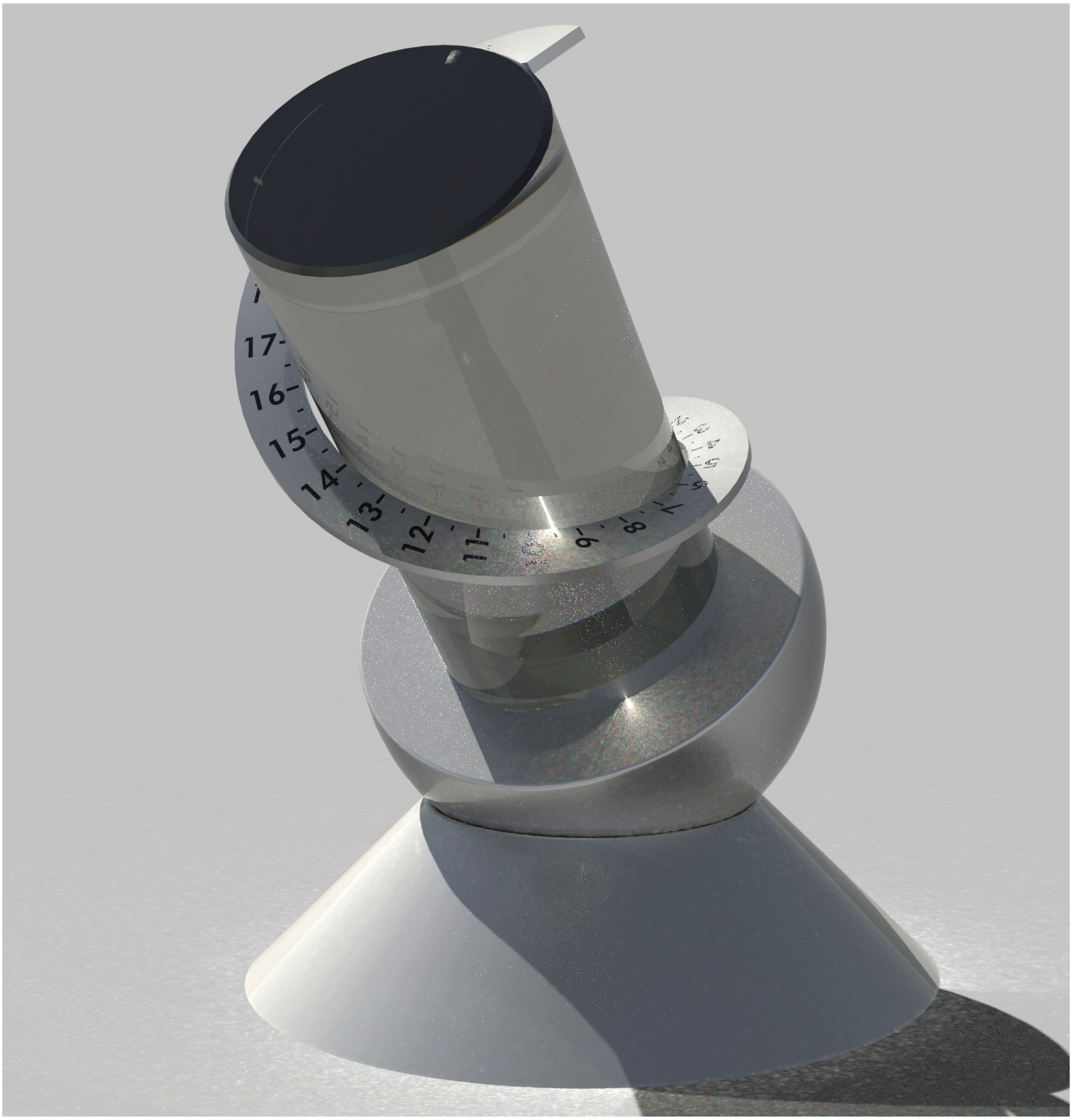

Fig. 20: The glass sundial at the summer solstice (20th June) at 9:30 solar time (LAT) at latitude 50°N..