ANTIQUE SUN & STAR DIAGONAL

Chris Lord

"A restored combined Sun & Star Diagonal c1880 made by Alexander Clarkson"

This is a fine example of an ingenious invention of Alexander Clarkson c1880. It combines the function of a conventional star diagonal prism and Herschel wedge in a single prismatic unit housed within a reversible cell. The cell and housing are designed to enable the prism cell to be withdrawn, flipped over, to convert the diagonal from Star to Sun. There is a small rectangular window in the housing through which the cell orientation can be identified. A beautiful accessory, artfully created, intended for use with small astronomical refractors.

Clarkson did not patent his invention, and it was copied by W. Watson & Sons, and subsequently made by Broadhurst, Clarkson & Co. Ltd. William Watson's workshop was at 313 High Holborn, London; Alexander Clarkson's workshop was at 338 High Holborn.

SUN & STAR DIAGONAL

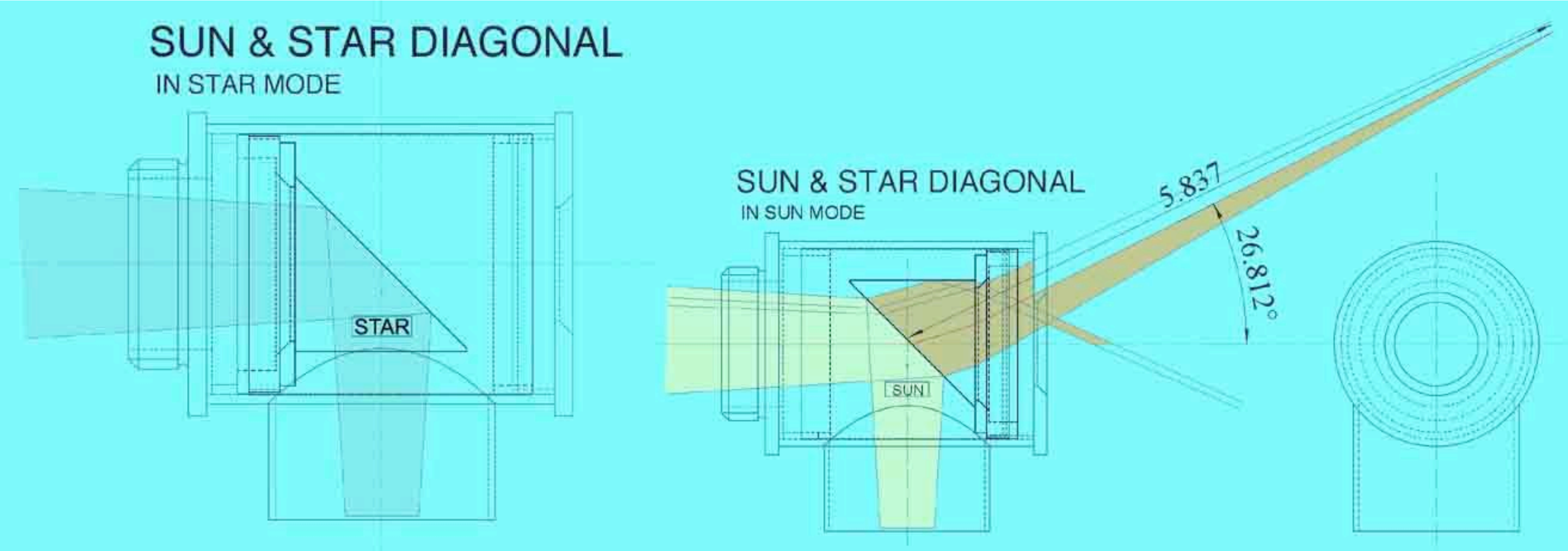
If their scarcity is anything to go by they were probably made in limited quantities. Separate Star diagonals and Herschel Sun diagonals of the same overall appearance were also made by the same firms at the end of the C19th and early thru' mid C20th. I am not aware of Broadhurst Clarkson discontinuing their manufacture, but I have come across none later than the early 1950's.

The design is very clever. Clarkson must have realised that a 45º x 45º x 90º prism could also be used as an alternative to a Herschel wedge if the hypotenuse received the incoming beam. 4.6% of the solar flux would be reflected off the hypotenuse, and the remainder refracted through the back face. An eyecap Sun filter could then be safely used to further attenuate the Sun's image, without excessive heating.

The right angle prism's hypotenuse receives the incident beam at at angle ~45º to the normal, and emerges refracted through 26º:48' to the optical axis. The aperture in the end cap allows the exhaust flux to escape where it comes to a rough focus about 6 inches behind.

When used with a 3-inch f/16 refractor approximately 3% of the abaxial rays undergo total internal reflection, but they too are directed through the exhaust port in the end cap. Roughly half the flux falls on the inside of the end cap which consequently gets quite warm.

To switch from Sun to Star mode, the end cap is unscrewed, and the prism housing slide out, flipped over 180º and reinserted and the end cap replaced. A slot in the prism cell engages with a pin in the diagonal housing to ensure correct alignment.



Raypath through the prism when in Star & Sun mode. To switch modes the end cap in unscrewed and the prism cell withdrawn, flipped over, and re-inserted, and the end cap screwed back in place. The small window in the diagonal housing displays the mode. The ray paths have been plotted assuming a 3-inch f/16 OG.


STAR
SUN & STAR DIAGONAL


VENTILATED
END
CAP
SUN & STAR DIAGONAL

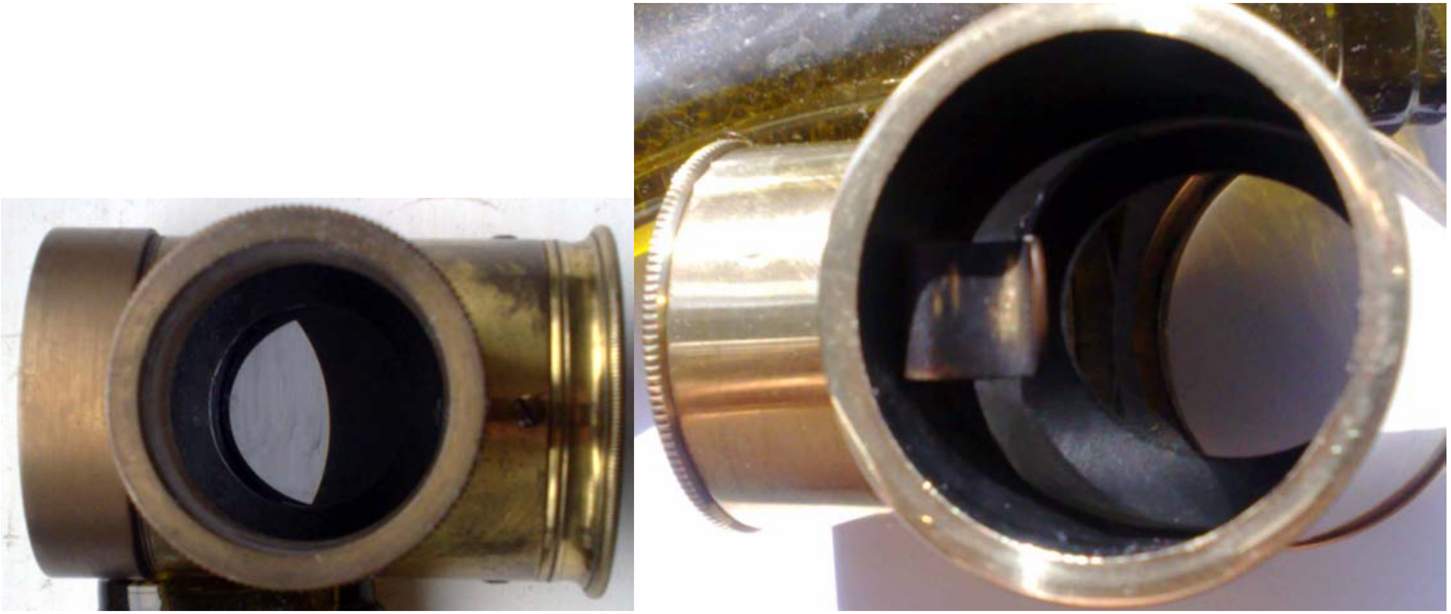

SUN & STAR DIAGONAL
STAR
SUN
END CAP
PRISM CELL
RAS DIAGONAL HOUSING

BRASS RAS FITTING COMBINED SUN & STAR DIAGONAL c1880. This ingenious accessory was invented by Alexander Clarkson whilst he was in business at 338 High Holborn, London, and subsequently made by Broadhurst, Clarkson & Co. Ltd. at 63 Farringdon Road, and copied by W. Watson & Sons, at 313, High Holborn.

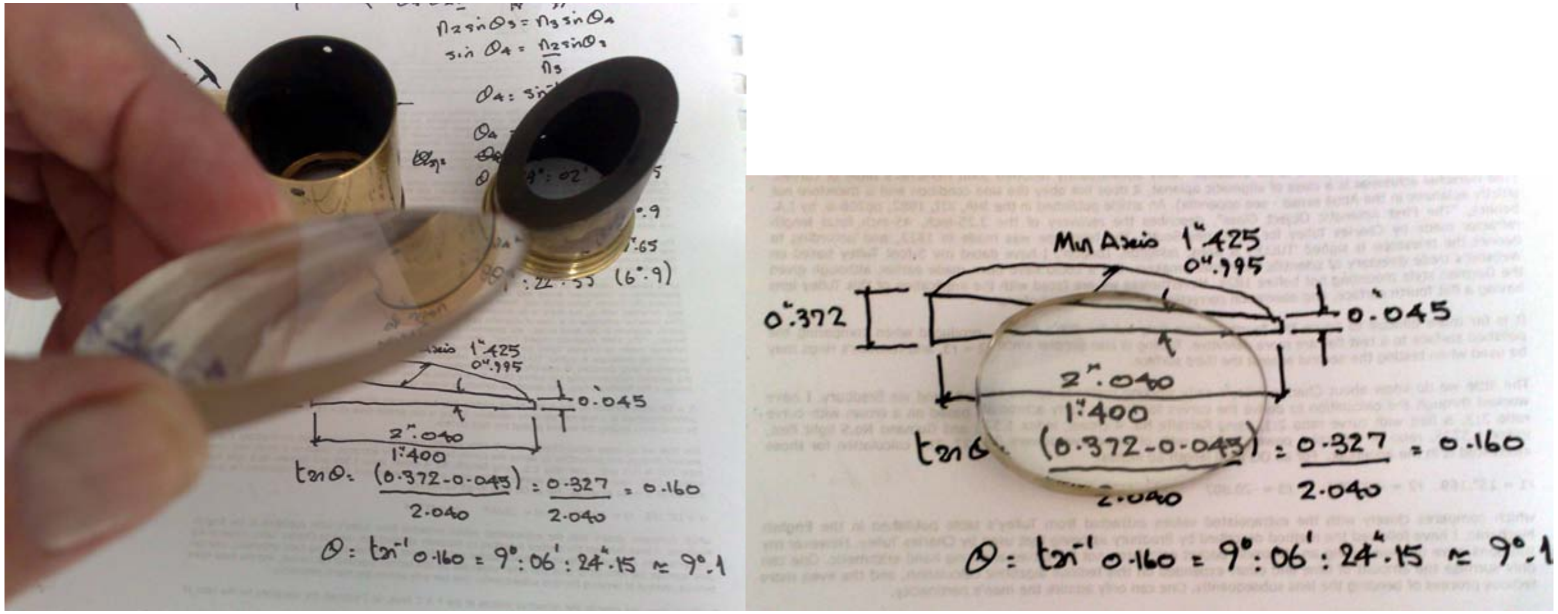
ANTIQUE SUN DIAGONAL

"Sun Diagonal c1890 made by Watson"

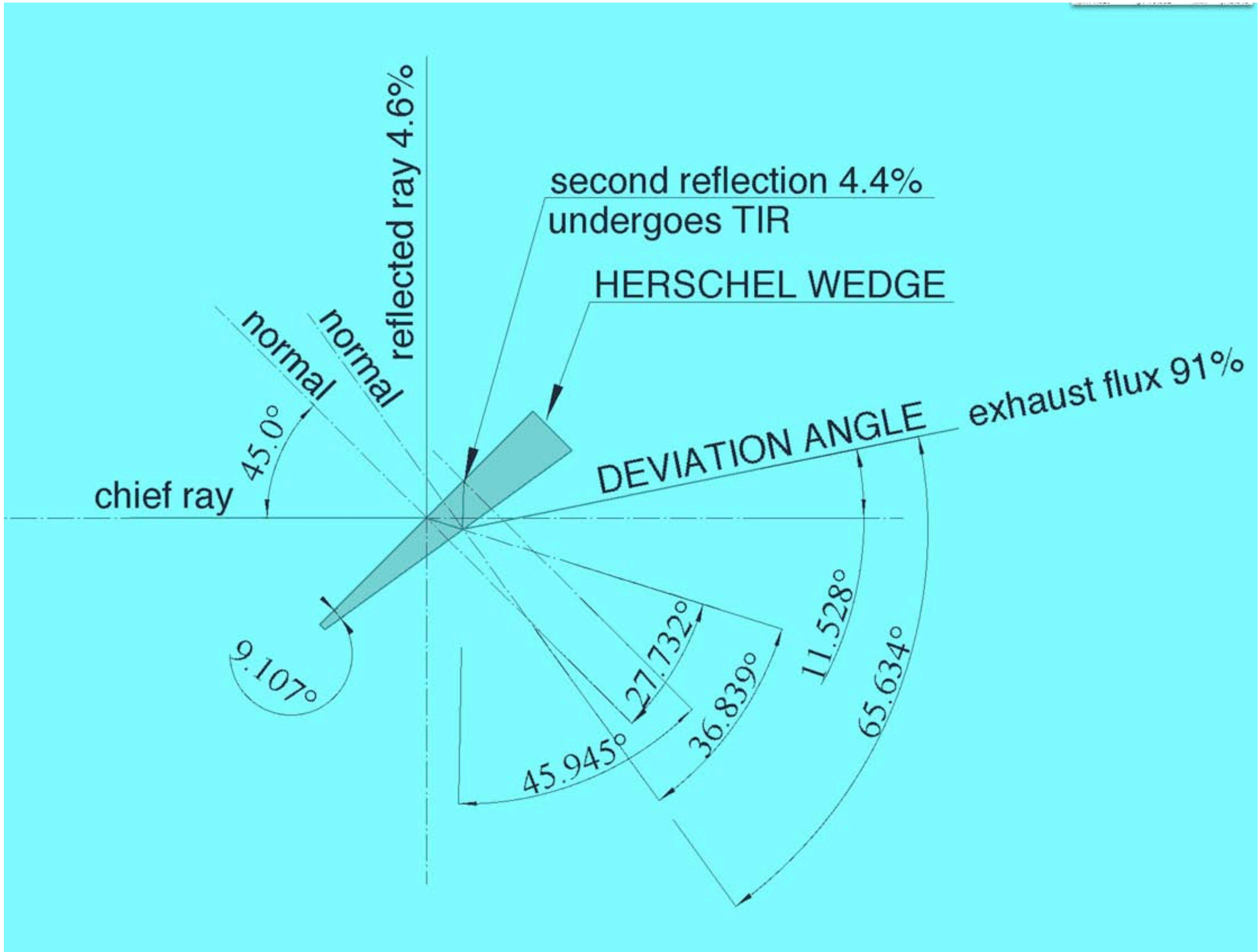
This is an example of Herschel Wedge, devised by John Herschel c1830, and made by Watson c1890. A Herschel Wedge is an elliptical wedge prism with both front and back faces polished optically flat, but the back face is tilted ~10º to the front face. Only 4.6% of the incoming flux is reflected into the eyepiece, the remainder is mostly directed out of the back of the flat housing (91%), and 4.4% reflected off the back face and subject to total internal reflection. The eyepiece must be fitted with a Sun screen eyecap filter.



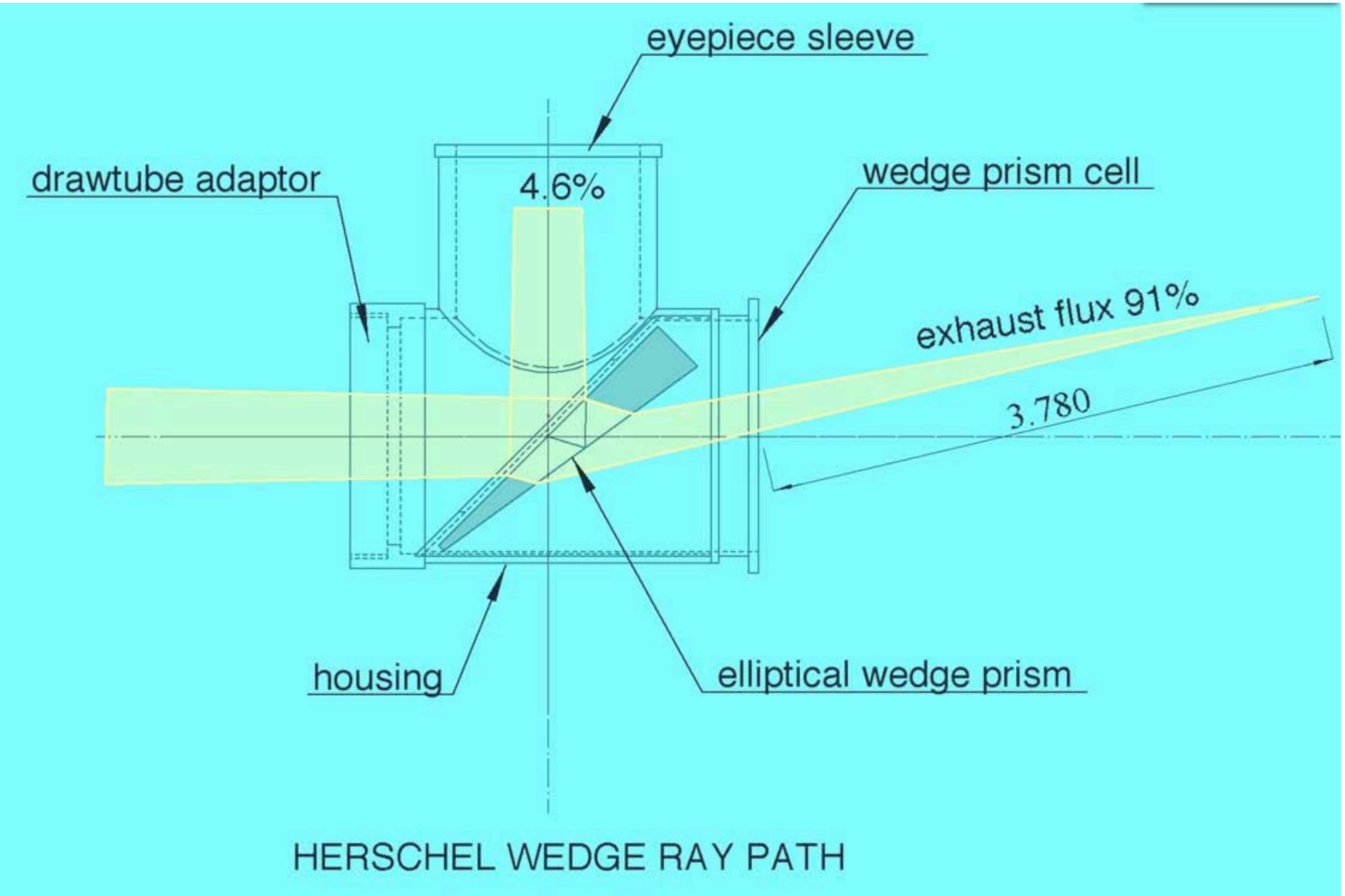
BRASS WATSON SUN DIAGONAL c1890. A Herschel Wedge solar prism, originally suggested by John Herschel c1830.



The dismantled Herschel Wedge showing the wedge shaped elliptical prism, the brass body and the wedge cell.

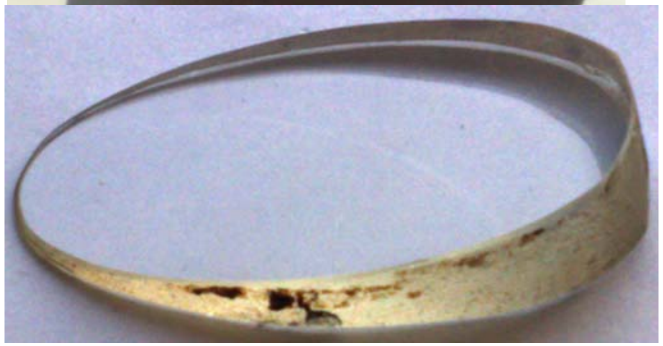


Ray diagram of the Herschel Wedge



Sectional drawing of Herschel Wedge RAY PATH

The optical theory of this device is straightforward. The front face is inclined 45º to the chief ray (optical axis) and partially reflected off the uncoated surface (4.6%). The remaining flux is refracted through the wedge (wedge angle 9º.1 in this example), partially reflected off the back face onto the front face and subject to total internal reflection (TIR 4.4%). The remaining flux is refracted out of the back face (91%) at a deviation angle of 11º.5 to the chief ray. The wedge does get warm, and the housing is designed to permit it to expand, being held in place by a steel spring clip. The exhaust flux comes to a rough focus only a few inches behind, and in refractors over 4 inches aperture, anything placed there would get very hot. A dense suncap filter has to be fitted over the eyelens to make the image brightness comfortable. This style of Herschel Wedge is unsuited for modern short focal length refractors, safe focal ratio limit is ~f/12.



Herschel wedge & cell. The wedge is an elliptical prism polished optically flat on both sides. The wedge angle is typically 10º; 9º.1 in this instance, to prevent the reflection off the back face entering the eyepiece which would produce a double image. Note the arrow mark on the thick edge indicating the front face.

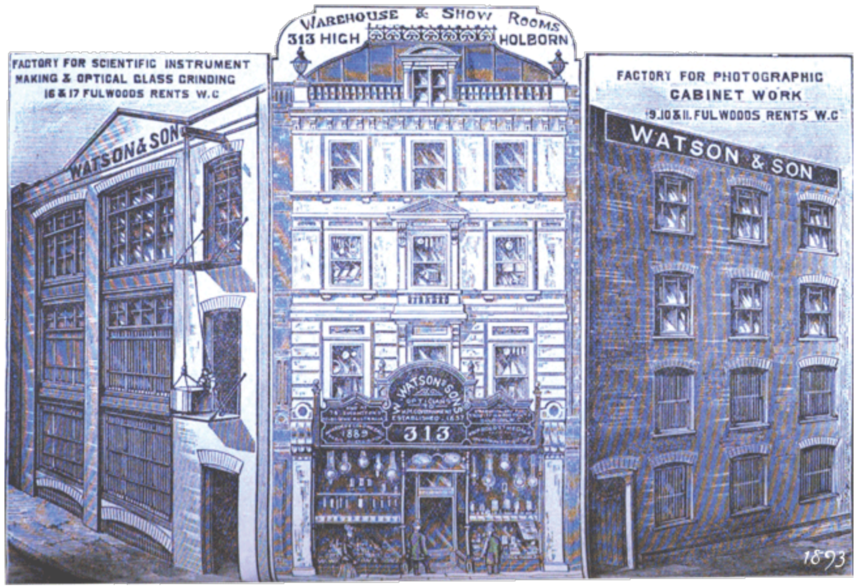
The elliptical wedge prism in this specimen is 2".040 major axis by 1".425 minor axis. The cell has an elliptical stop inclined at 45º. major axis 1".400 by minor axis 0".995. The elliptical stop effectively stops down the elliptical wedge prism to 1-inch aperture. The wedge prism is polished optically flat on both sides, and the front face is marked by a pencilled arrow on the thick edge.

The reason the elliptical wedge prism is wedge shaped is to prevent the reflection off the back face entering the eyepiece and producing a double image. The wedge angle is not arbitrary. For TIR the critical wedge angle is 13º.422 for crown glass. This wedge angle is 9º.1, causing the exhaust flux to exit 65º.634 to the chief ray. When the wedge angle equals the critical angle for TIR, the exhaust flux would emerge at right angles to the chief ray, flood the eyepiece field and overheat the brass body. If the wedge angle is greater than the critical angle for TIR, all the exhaust flux is totally internally reflected, possibly overheating the wedge itself, certainly putting it under strain to the point where the image would become distorted due to astigmatism from the warped front surface.

The potential danger when using this style of Herschel Wedge on a refractor, focal ratio greater than f/12, f/16 say, is the observer forgetting to add the eyecap sun filter. The unfiltered image is approximately 2000 times brighter than the Full Moon. A Herschel Wedge does not block harmful UV or IR. This is done by the eyecap sun filter. However, having added this word of caution, it is fairly obvious the exit pupil is overly brilliant even if you do forget to add the filter! It is also important to place yourself sideways to the diagonal, otherwise, if you are in line, the exhaust flux is focussed onto your chest.

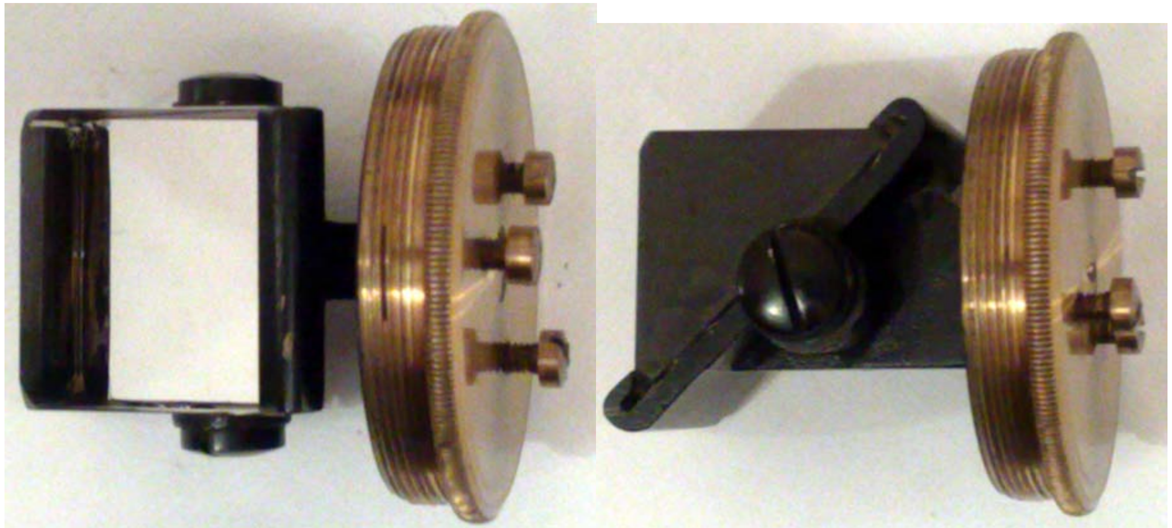
ANTIQUE/VINTAGE STAR DIAGONAL

"Star Diagonal c1948? made by Watson"



This is an example of Star Diagonal made by Watson c1948? Signed Watson & Son Ltd, London. The family firm traded as W. Watson & Son from 1868 and as a limited company between 1908 & 1948.

However this star diagonal may not be antique. It has black cheese head nylon & fibre washer cell screws. Nylon was introduced in the mid 1930's, so either it was repaired in the intervening years, or made in the 1940's probably after WWII. The fitting is 1".204 not the RAS astronomical telescope standard of the late C19th thru' 1960's. 1".204 was also adopted by Wray. I have 3 Wray Huyghenian eyepieces in my collection which fit this Watson diagonal.



Watson & Sons Ltd., 1".204 push fit star diagonal showing the assembled diagonal, its component parts comprising the signed brass lacquered body, the drawtube nosepiece, the eyepiece sleeve, and the prism cell and rear flange with collimation screws. Note the prism cell is secured by black nylon cheese head retaining screws & fibre washers, implying the diagonal was either repaired at some stage, or made after nylon screws began to be commonly available, maybe post WWII.