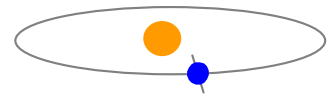


The FLUID OPTICS™ letter

La lettre des Syzygies



March, 2001

EDITORIAL

We have the pleasure to present you the letter of the syzygies of the spring equinox in which you will find two articles: a first on the filtering of the infrared by solid, interference or liquid filters and the second on a modular lighting developed by one of our subscribers.

The inventors of the Fluid Optics

PRODUCTS

The LUPION

We take advantage of this article to present you Lupion, a lighting product developed by one of our subscribers.

The LUPION is a device of totally flexible lighting, according to necessities. This lighting was created at the request of the collectors to highlight precious objects, sensitive to infrared

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SUMMARY

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MEASURES

THE FILTERING OF THE INFRARED

One of the major problems of the lighting results in using lightsources which emit infrared besides the visible light. This infrared radiation is unwanted and warms exposed subjects. It is so necessary, in most of cases, to filter the radiation going from these lightsources.

The most used filters are the anticaloric glasses. These filters eliminate the infrared by absorbing within their mass this type of radiation.

Sometimes, we find also interferential filters. The infrared are eliminated by using the physical phenomenon of interference.

These solid filters or interferential are not the single solution of the filtering of the infrared. Indeed, one can also use liquids and obtain a good result. As for the solid filters, the liquid filters absorb the infrared.

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To test the filtering of these filters, we have 5 anticaloric glasses :

CALFLEX (thickness 2mm), KG1 (thickness 3mm), KG2 (thickness 3mm), KG3 (thickness 6mm) and KG4 (thickness 2mm),

one interferential filter : Filter IR3

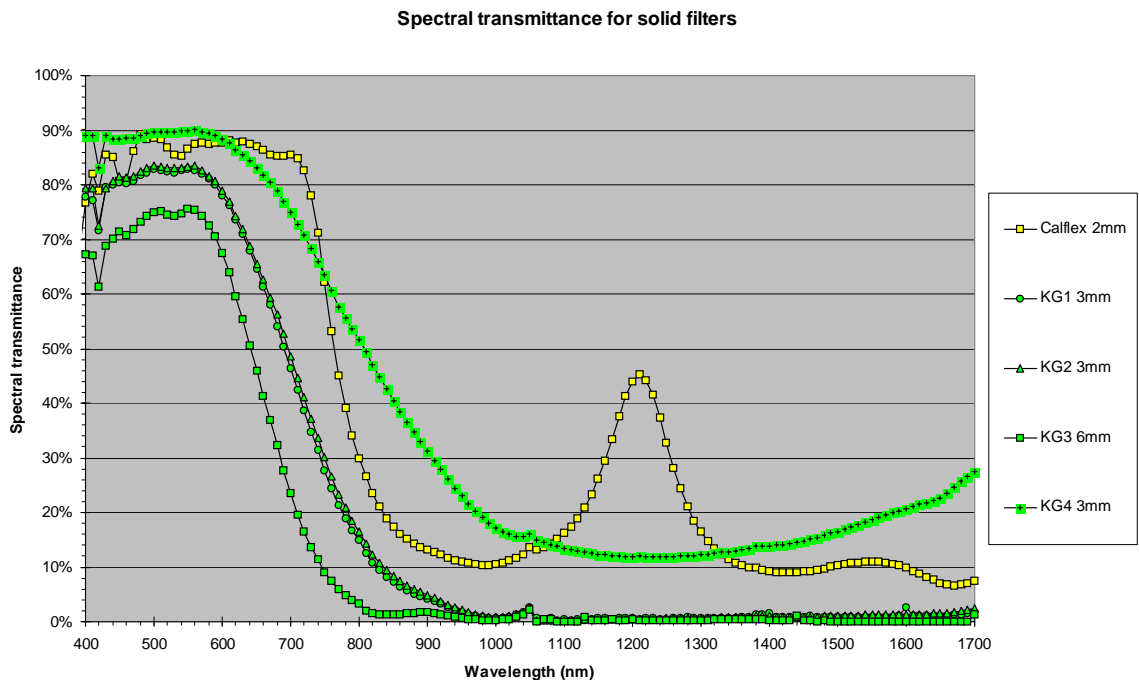
and a cell in quartz suprasil with a light path of 10 mm.

To measure these filters, we use a spectro-radiometer consisted of a tungsten halogen source, a monochromator, a compartment test of samples and a radiometer. This chain of measure allows the study of the transmittance or the reflectance on a spectral range going from 340 nm to 1700 nm.

For every filter, the spectral transmittance is calculated for every wavelength, by comparing the spectrum obtained with the sample with the spectrum obtained without sample.

We study every filter on the visible (400 nm to 800 nm) and on near infrared (800 nm to 1700 nm). Study in the visible allows us to measure the absorbed visible light which is a loss not wanted for the applications of lighting.

Solid filters



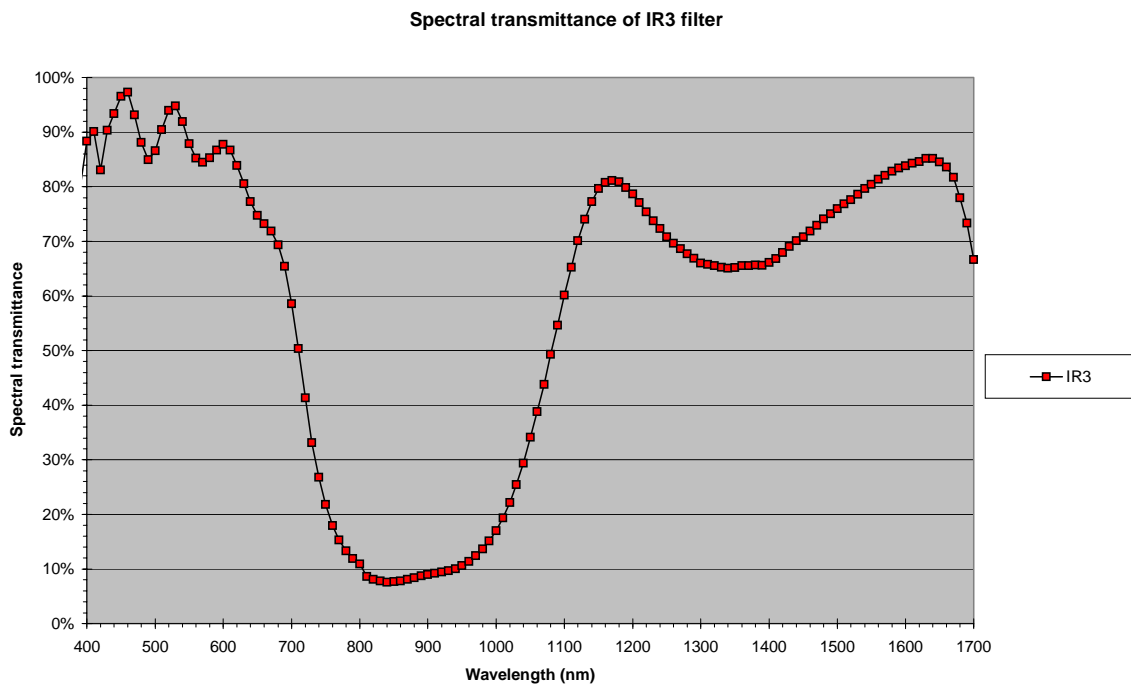
KG1 , KG2 and KG3 filter absorbs the infrared well but a lot of visible light is also absorbed especially on

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red (700 nm to 800nm). The filter KG4 and Calflex absorb less visible but it is to the detriment of the absorption of the infrared which is less important. These glasses, are renowned to resist to temperatures going to 600°C.

Interferential filter



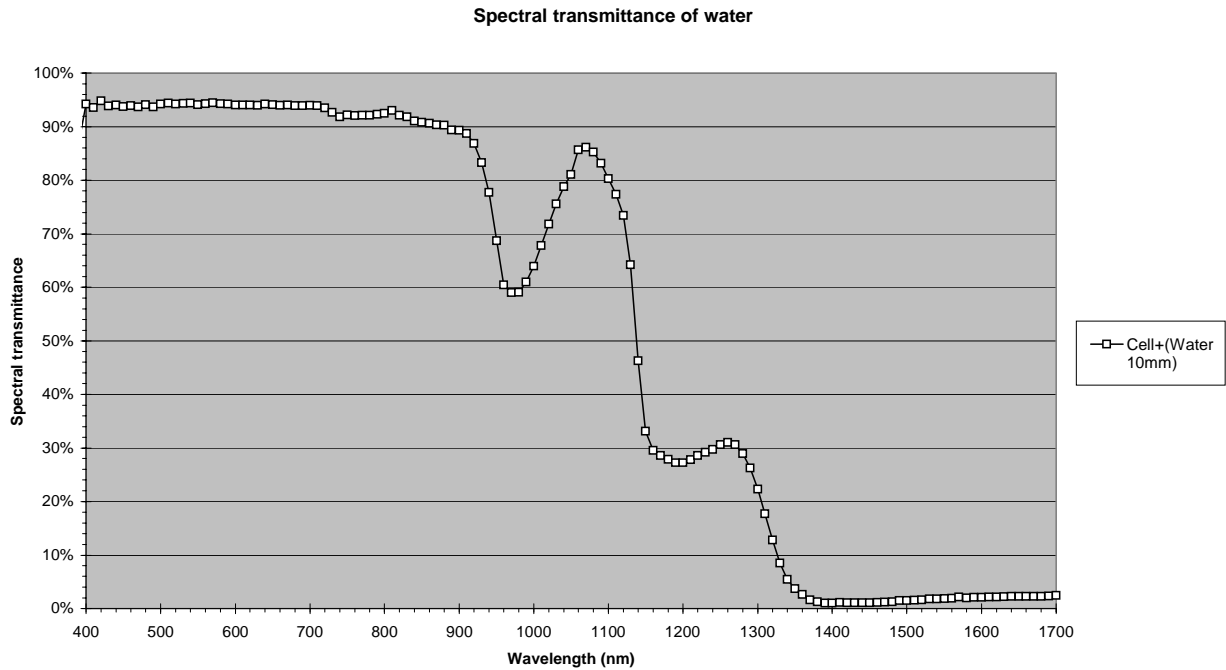
This IR3 filter reflects well the light on the spectral range of about 800 nm to 1000 nm. Above this spectral range, It transmits the infrared. This type of filter resists to temperatures of the order of 450°C.

Liquide filter

One of the most common liquid filters absorbing the infrared is the water. Obviously, water alone can not be used industrially because it degass and pollutes itself quickly with photosynthesis. So, it is necessary to add a chemical substance to avoid these inconveniences.

We developed a first industrial optical liquid filter able to keep the physical properties over a period superior to 13 months. If it is necessary, studies and tests could be still led to improve the performances of this filter. However for our tests of laboratory, the distilled water is amply enough for us.

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We notice that with only 10 mm of water, we obtain an important absorption of the infrared from 1400 nm. Between 800 nm and 1400 nm, absorption is not very good. On the other hand the water is very transparent in the spectral range of the visible (400 nm to 800 nm).

To absorb more radiation between 800 nm and 1400 nm, it is necessary to use a bigger thickness of water. It is for it that we are going to calculate the transmittance of the water for a bigger thickness.

Internal transmittance of water

The previous measures of the transmittance of the water are erroneous because of the reflectance of dioptric interfaces of the cell : Air / quartz, Quartz / water, Water / quartz and Quartz / air. The reflectances can be estimated.

Our measures are made for almost zero incidence. The coefficient of reflection for a zero incidence ($i = 0^\circ$) for the passage of an environment of refractive index n_1 into an environment of refractive index n_2 is given by :

$$R = \left(\frac{n_2 - n_1}{n_2 + n_1} \right)^2 \quad (1)$$

In view of the equation (1), the coefficient of reflection for the passage of an environment of refractive index n_1 to an environment of a refractive index n_2 is equal to the coefficient of reflection for the passage of an environment of refractive index n_2 to a refractive index n_1 .

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By neglecting multiple reflections on the internal surfaces of the cell, the factor of transmission of the cell can be expressed by the following equation:

$$T_{cell} = \left[\left(1 - \left(\frac{n_{air} - n_{quartz}}{n_{air} + n_{quartz}} \right)^2 \right) \times \left(1 - \left(\frac{n_{quartz} - n_{water}}{n_{quartz} + n_{water}} \right)^2 \right) \right]^2 \quad (2)$$

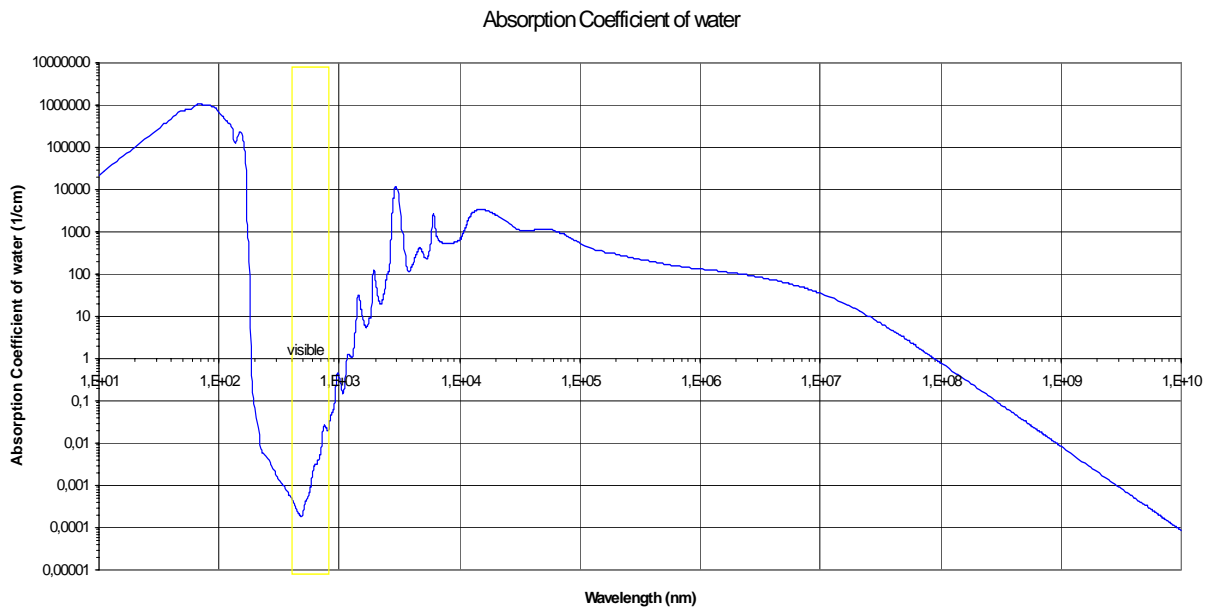
The refractive indexes are considered as constant on the spectral range studied.

With $n_{air} = 1,0$, $n_{water} = 1,333$ et $n_{quartz} = 1,458$, we obtain $T_{cell} = 0,9280$

To get the internal transmittance of the water, it is necessary to divide the transmittance measured by the transmittance of the cell. We have a problem because our measures of the water in the region of the visible are slightly superior to 92,8%. We can not so in this spectral region deduct from it the internal transmittance of the water.

The results of the absorption of the water in the scientific literature

In different scientific works, the only differences of the results are located in the band of the visible spectrum. Indeed as the absorption of pure water in the visible is very low, it becomes very difficult to measure the absorption without a very elaborated instrument. The best results for the visible were obtained in 1997 *{Pope and Fry 1997}*. These results show that absorption is minimum at the wavelength 418 nm ($0.0044 \pm 0.0006 \text{ m}^{-1}$). It explains the blue colour of the water in the big depths of the ocean. In 1981, the absorption coefficient of water was established *{Segelstein 1981}* on a big area of wavelength (10 nm to 1 m).



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Comparison of our measures with reference results

The internal transmittance of the water can be calculated from the coefficient of absorption with the relation(3).

$$T_{wi}(d) = e^{-a(\lambda) \times d} \quad (3)$$

where “a(λ)” is the coefficient of absorption (1 / cm) of the water and “d” is the thickness of water (cm) crossing by the light.

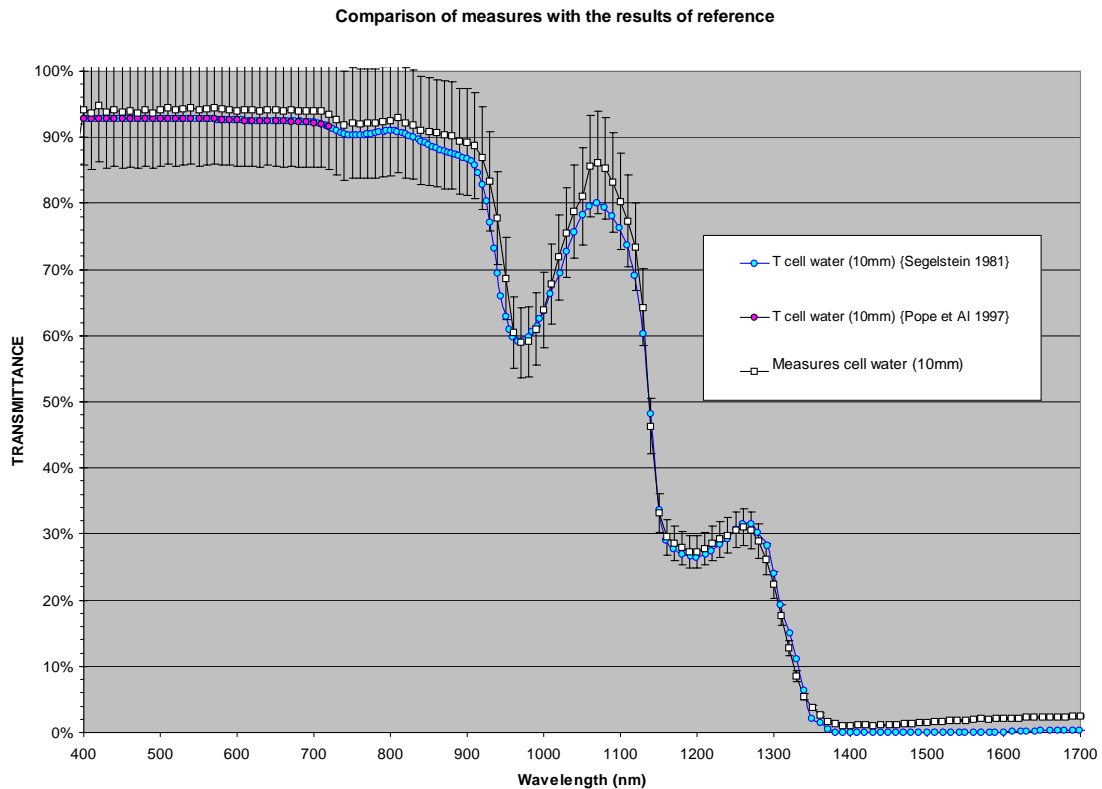
The reference results for our cell of light path of 10 mm are given by :

$$T_{ref} = T_{cell} \times T_{wi} \quad (1) \quad (4)$$

To compare results, it is necessary for us to calculate uncertainty on the transmittance which we measured. By taking into account the relative uncertainty of measure of the radiometer, we can calculate relative uncertainty on the measured transmittance:

$$\frac{u_T}{T} \approx 9\%$$

We appeared, on the following graph, relative uncertainty for our measures.



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We notice, in the previous graph, that our measures of transmittances, until 1400 nm, for a cell of water of 10 mm, are in accordance with reference results {Segelstein 1981} {Pope and Fry 1997}. Over 1400 nm, a little difference remains. This difference results from the difficulty to measure very weak illuminations.

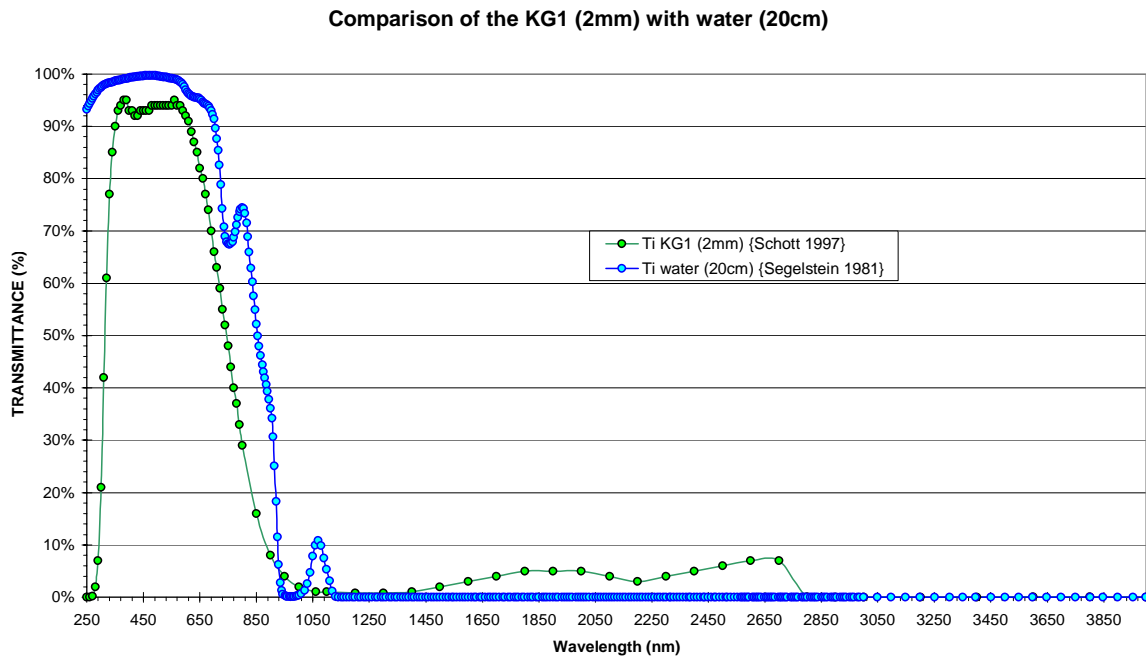
Comparison of the internal transmittance of the water and the internal transmittance of the KG1

To compare these two types of filters on the visible and the infrared, we compare manufacturer's values for the internal transmittance of the filter KG1 for a thickness of material of 2 mm {Schott 1997} to the reference results of the water {Segelstein 1981}.

We saw that a thickness of water of 10 mm was not sufficient to filter drastically the infrared. By experience, to evacuate big powers, we take as minimal thickness of fluid 20 cm.

Measures made on the previous samples allowed to study the transmittance only on the visible and infrared close.

Given that we have values of transmittance for wavelengths until 4000 nm {Segelstein 1981} {Schott 1997}, we can compare the internal transmittances of these two filters in the visible and the infrared.



We can calculate the average transmittances in the visible and the infrared and compare them together.

Wavelength(nm)	Ti KG1 ep=2mm	Ti water ep=20cm
400 to 800 nm	79%	90%
800 to 4000 nm	4%	4%

We notice for these two filters that average absorption in the infrared are equivalent. On the other hand, given the big transparency of the water in the visible, we gain 11% of light passed on with the water filter.

Conclusion

All these results show that for small powers the anticaloric glasses are excellent filters for the infrared. However, it is necessary to use them under a thin thickness to prevent the losses of visible light especially in the red.

For biggest powers, for example for a generator with optical fibre of power from 2kW to 10kW, It is no possible any more to use anticaloric glasses because the sources temperatures reach the order of 1000 °C.

The manufacturer of these anticaloric glasses *{Schott 1997}* gives a temperature of transformation of the order of 600°C. All the attempts which we made with big powers have provoked destruction of the solid filters even well ventilated. In that case, there is no more choice, it is necessary then to use fluids as water which can be cooled with a cooling system. These coolants can have other properties. For example, they can also serve for cooling all the constituents of the optical system by conceiving an adequate cooling circuit. Moreover, the MEGALUX company conceives dynamic Fluid Optics which are at the same moment an optic and an infrared filter.

Pope and Fry 1997 : R. M. Pope, E. S. Fry, "Absorption spectrum (380-700 nm) of pure water. II. Integrating cavity measurements," *Appl. Opt.*,36, 8710-8723, (1997).

Segelstein 1981 : D. J. Segelstein, "The complex refractive index of water," University of Missouri-Kansas City (1981).

Schott 1997 : Catalog Optical Glass Filter, 1997 SCHOTT Glas Mainz.

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and ultraviolet.

This product is more useful in the shop windows of exhibition of small dimensions, waterproof in the dust.

Our advices and our experience allowed our subscriber to stop 67% of thermic effects due to the infrared, and limit the increase of the temperature, inside these shop windows, in +5° with regard to ambient temperature.

The quality of the produced illumination is due largely to the possibility of distributing lighting in several sources, and in the choice of halogeneous capsules anti-ultraviolet of small power.

The variation of the number of modules of lighting goes from 2 to 6. Their assembly can be made without equipment, in some seconds. This formula favours the flexibility of the product. It is now possible to highlight rare and fragile objects. This precaution is required by the collectors and the conservatives of museums.

First better results were obtained with the collectors of ancient jewels and of miniatures, railway or motor designers, on salons and different demonstrations.

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NEWS

If there is a subject which you wish to see treating in this letter, you can directly contact us by email at the address:

syzygies@optique-fluide.org

You can also join **MEGALUX**, the company charged to exploit the Fluid Optics, at the address:

info@megalux.com

NEXT LETTER

The next Letter “La lettre des Syzygies” will appear for the summer solstice.