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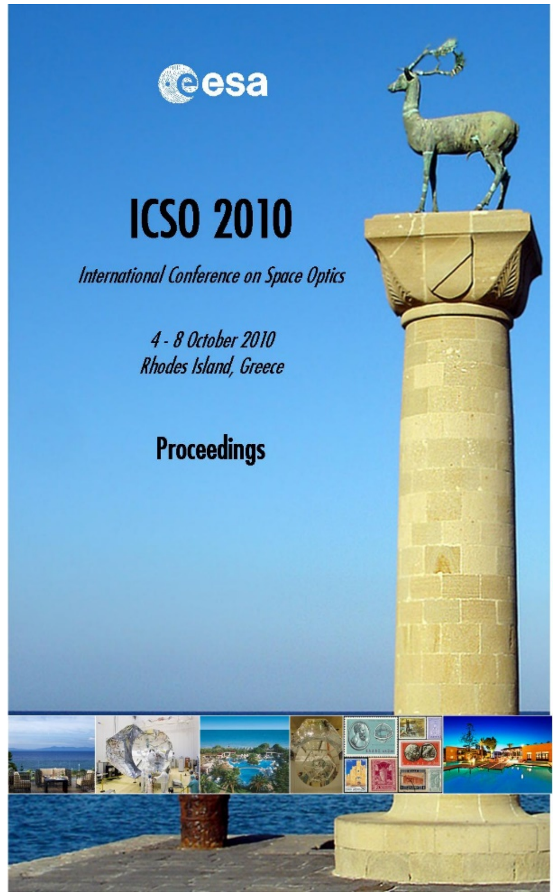

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EXTENSION OF THE ABSOLUTE RADIOMETRIC CALIBRATION FACILITY AT TNO

O.E. van der Togt, D. ten Bloemendal, M. Eschen, N. Dijkhuizen, J.J.M. Groote Schaarsberg, G.C.J. Otter
TNO Science and Industry,The Netherlands

ABSTRACT

The Absolute Radiometric Calibration Facility (ARCF) at TNO operates a unique optical scatter measurement set-up for the characterization of optical components for space applications and has been recently refurbish to extend the working wavelength domain from UV/VIS/NIR to SWIR, making accurate measurements possible in the entire 240-2400 nm range. A second extension currently being performed is the addition of an optical parametric oscillator (OPO) laser light source, tunable over the same wavelength range. The increased light levels made possible by this new source will improve the signal-to-noise-ratio (SNR), significantly reducing measurement time and potentially further increasing the measurement accuracy. In this article we will present the challenges encountered in expanding such a setup to the SWIR and their solutions, show the new capabilities of the setup and explain the possibilities of using tunable pulsed OPO lasers in calibration applications.

II. ARCF CONCEPT AND UPGRADE

The Absolute Radiometric Calibration Facility (ARCF) is a class 100 clean room capable of measuring the bidirectional scatter distribution function (BSDF), bidirectional reflectance distribution function (BRDF) and bidirectional transmittance distribution function (BTDF) with a 0.5% absolute error in the visible domain. The facility has been used in the past for analyzing the Medium Resolution Imaging Spectrometer (MERIS) diffusers and during several on-ground calibration campaigns for SCHIAMACHY, Ozone Monitoring Instrument (OMI) and GOME-2. Fig. 1 shows a schematic description of the ARCF measurement set-up. A wavelength tunable light beam is created by a SuperQuiet Xe lamp or by a quartz tungsten-halogen lamp and enters a computer controlled double prism monochromator that is capable to transmit any spectral band within 240 -2400 nm. Light exiting the monochromator is collimated and has a maximum diameter of 40 mm. Next, this beam encounters a Suprasil quartz window, which can reflect, respectively transmit the light towards two different directions. One direction is towards the reference detector, for a baseline measurement. The second direction is towards the optical rail where the data detector and sample stand. Both the reference and data detector assemblies contain the same components including telescope, housing, single-batch detectors, and synchronous readout. The data detector assembly is positioned on an arm capable of a 360° rotation in a horizontal plane. For polarization purposes, a Glan-Thompson and Brewster polarizers could be implemented into the set-up. The ARCF goniometer is placed on a no-vibration optical table and can be rotated around three different axes and translated along one, providing a complete out-of-plane measurement possibility. The rotation and translation settings can be set with an accuracy smaller than 0.003°.

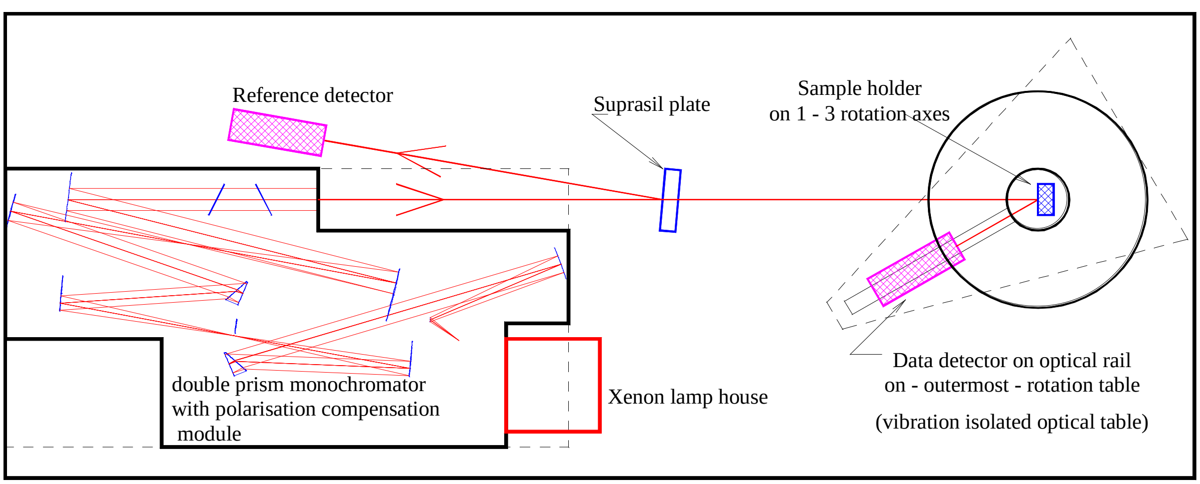

Fig. 1. Schematic drawing of the Absolute Radiometric Calibration Facility

Originally the detector assemblies were designed to work in the UV/VIS/NIR domain, between 200 and 1100 nm, being primary intended to be used for the calibration of diffuser plates and diffuser assemblies. Recently the ARCF has been upgraded with an IR detector assembly, which operates between 700 and 2700 nm. Given the characteristics of the acquired IR detector- a Indium Gallium Arsenide detector with an active diameter of 3 mm, which is 3 times smaller than that of the UV/VIS/NIR detector-, a redesign of the detection system was necessary. This new optical system consists of three different components as seen in Fig. 2.: the telescope, the detector unit and the light trap unit.

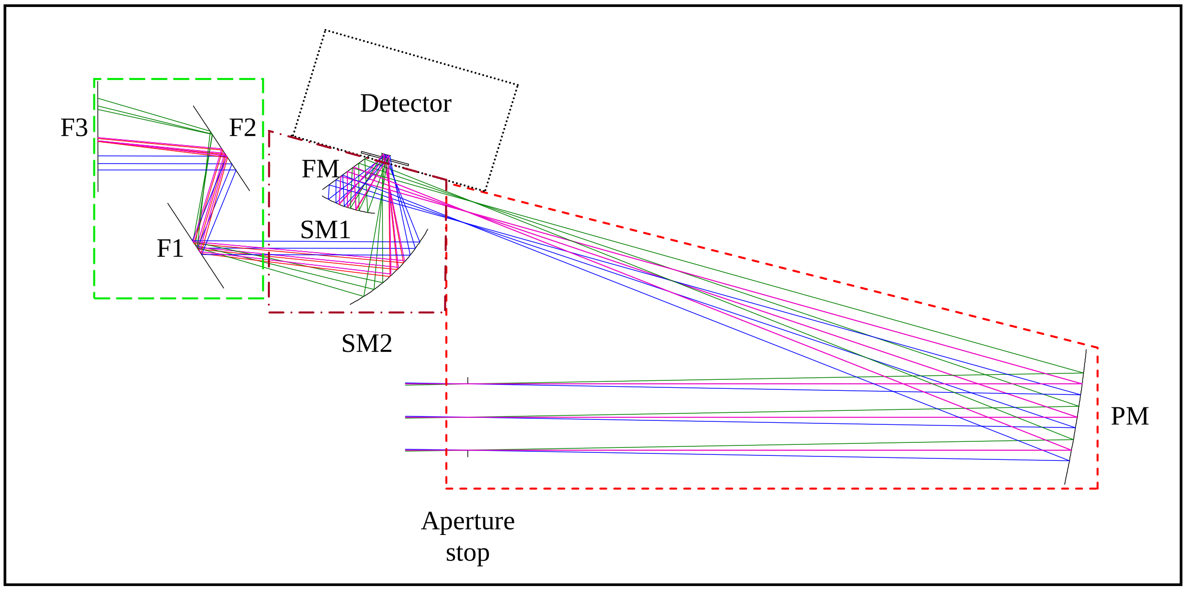

Fig. 2. 2D layout of the ARCF IR detector assembly with identifying components labels.

Radiation, from 700 nm to 2700 nm, coming from the observed object enters the telescope under an angle of maximum ±1° through an aperture of 21 mm and is focused by an of axis parabola at the field stop. The telescope is mounted in a mechanical unit, separate from the detector and light trap, to prevent straylight from coming into the detector.

From the field stop, radiation is sent to the detector, by means of two mirrors: a folding mirror to bend the incoming ray bundle and a spherical mirror to focus it onto the 3 mm diameter circular active surface of the detector. Afterwards, the radiation reflected by the detector is collected by a spherical mirror and sent to the light trap unit. The spherical mirror plays the same role as that one before the detector, mainly to reduce the size of the ray bundle coming from the detector.

Mechanically, the folding mirror, the two spherical mirrors and the detector surface are placed in a single housing to prevent straylight caused by the other system's components to reach the detector. The light trap unit consists of three stacks of filters, each stack being formed by a neutral density glass (Schott NG1 filter) and an IR absorption filter (Schott KG5 filter).

All mirrors are produced by TNO and are made of RSA-905. This alloy is characterized by ultra fine and homogeneous microstructures, is easier machined than standard Al-alloys (like AISI-6061) and has a better shape stability and a lower achievable surface roughness (typical RMS values of 2 nm or less).

System specifications, such as the focal length, entrance pupil diameter, field of view (FOV) are given in Table 1. This table also contains the wavelengths used in the design and in the analysis of the performance of the optics.

Table 1. Specifications of the IR detection optical system

Parameter	Value
Effective focal length (mm)	376.25
Entrance pupil diameter (mm)	21
F/ #	17.9
FOV (º)	±1
Wavelengths (nm)	700-2600
Detector size (mm)	3

In terms of performance, the entire radiation entering the optical system through the aperture stop reaches the detector as can be seen in Fig. 3.

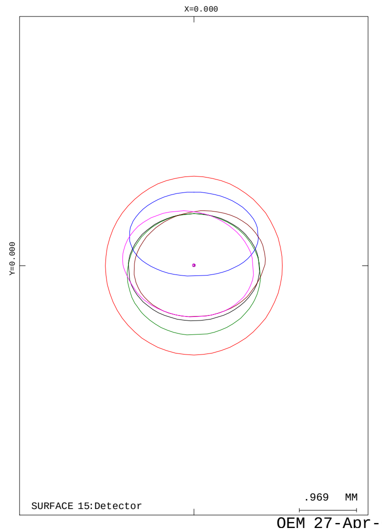

Fig. 3. Footprint plots at the detector of the IR ARCF configuration. The effective aperture of the detector is drawn in red. The footprint for the on-axis field is represented in black. The footprints for the full field are shown in blue, brown, green and pink.

The overall mechanical design is illustrated in Fig. 4., with the telescope housing (red), the detector (black), the detector unit (red-oxide) and the light trap (green). The filter stacks are also indicated (orange) in the light trap unit. All system components, with the exception of the parabolic mirror and the detector, are placed within the manufacturing tolerances. The parabolic mirror is positioned so that the incoming radiation is focused in the field stop plane and the detector is moved along the optical axis so that the radiation fits within the photodetector surface. The mechanical mount is placed on two adjustable feet, which can also be used for alignment. Adjustment is possible on the vertical scale, including rotation along and perpendicular to the vertical axis, as well as rotation along the axis oriented from the viewer towards the paper.

The goniometer can perform polarized and unpolarized scatterd measurements, both in absolute and relative modes, on samples up to ~1000 mm (depending on the angular range to be measured). The accuracy of ARCF BSDF measurements is 0.5% (absolute) and 0.3-0.4% (relative) over the complete operating wavelength range.

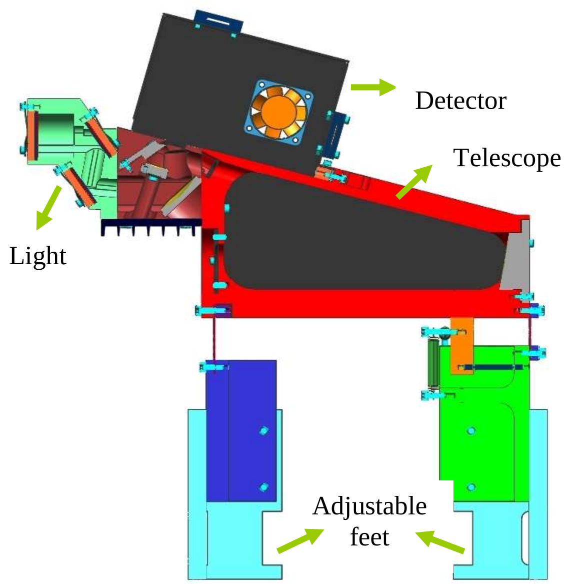

Fig. 4. Mechanical design for the IR optical detection system.

At the moment the ARCF is upgraded with EKSPLA NT242 tunable optical parametric oscillator (OPO) laser, which will replace the monochromator (see Fig.1) in the current configuration. The laser has a no-gap wavelength range from 210 up to 2600 nm and generates 4-7 ns pulses at a rate of 1000 Hz. The power ranges from 40 mW in the UV and SWIR up to 500 mW in the visible range. The bandwidth is close to 5 cm^{-1} meaning that it ranges from ~0.02 nm at 210 nm to ~3nm at 2500 nm.

Implementing the laser is not straight forward. The principle of the setup is that a large homogenous beam is oversized with respect to the detector footprint on the diffuser. This limits the stray light sensitivity but makes the setup sensitive to inhomogeneity of the input beam. The laser source does not deliver a homogenous beam so this needs to be homogenized. In addition the shape of the laser beam is wavelength dependent. Currently the beam shape is investigated in detail to optimize the homogenizing optics.

Also the laser delivers polarized light. This can be dealt with in different ways; we can measure with polarized light, provided that we can rotate it, or we can depolarize the light. So far we have made the choice of using the polarization of the laser.

More complex is the expected speckle behaviour of the laser. The output of the detector will depend on how many speckles there are within the detector surface. If the number of speckles is to low it will generate a significant contribution in the error budget. The number of speckles will depend on the test sample and can therefore not be predicted. However by rotating the test sample over a set of small angles the speckle pattern will change. In such way a number of independent speckle patterns can be produced. By averaging these patterns the effect can be minimized. It is therefore believed that speckle behaviour can be dealt with such that it will yield no significant error contribution.

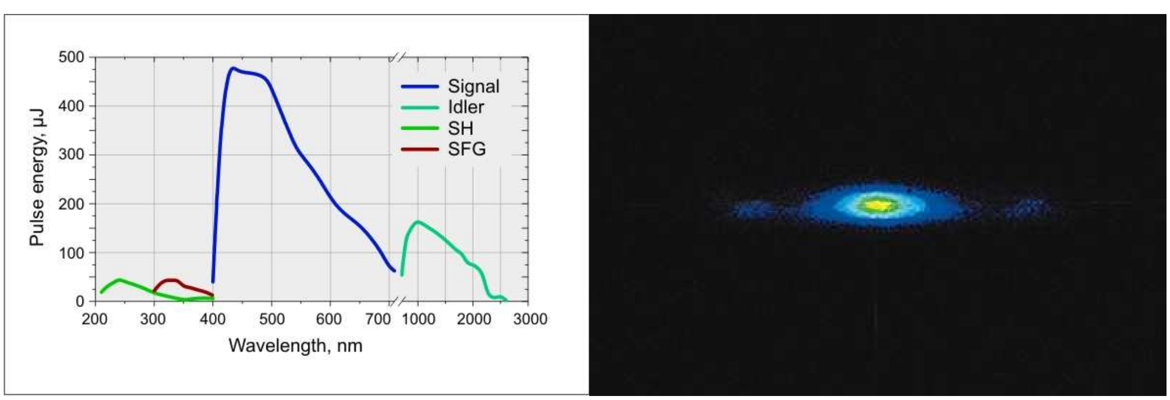

Fig. 5. Laser characteristics of EKSPLA NT242 OPO laser: on the left side the laser power and on the right side the beam profile as provided by the manufacturer.

CONCLUSIONS

In this paper we have presented the upgrade of the ARCF so that BSDF measurements in the SWIR domain can be also performed. The facility currently consists of two interchangeable detector assemblies, capable of working in the UV/VIS domain (200 – 700 nm) and the IR domain (700-2400 nm) with an accuracy of 0.5% absolute error.

We believe that with the implementation of the EKSPLA NT242 laser the measurement's accuracy can be further improved over the complete wavelength range.