The DLR Complex Irradiation Facility (CIF)

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ABSTRACT

The DLR Institute of Space Systems in Bremen is commissioning a new facility to study the behavior of materials under complex irradiation and to estimate their degradation in a space environment. It is named Complex Irradiation Facility (CIF). With CIF it is possible to irradiate samples simultaneously with three light sources for the simulation of the spectrum of solar electromagnetic radiation. The light sources are a solar simulator with a Xe-lamp (wavelength range 250-2500nm), a deuterium-UV-source (112-400nm), and an argon-gas-jet-VUV-simulator. The latter enables the irradiation of samples with shorter wavelengths below the limitation of any window material. The VUV-simulator has been validated in the wavelength range between 40 and 400nm at the PTB (Physikalisch Technische Bundesanstalt) in Berlin by calibration which uses synchrotron radiation. In addition to the different light sources CIF provides also electron and proton sources. The charged particles are generated in a low energy range from 1 to 10 keV with currents from 1 to 100 nA and in a higher range from 10 to 100 keV with 0.1 to 100 µA. Both particle sources can be operated simultaneously. In order to model temperature variations as appear in free space, the sample can be cooled down to liquid Nitrogen level and heated up to about 450 K by halogen lamps behind the target during irradiation.

The complete facility has been manufactured in UHV-technology with metal sealing. It is free of organic compounds to avoid self-contamination. The different pumping systems achieve a final pressure in the 10^{-10} mbar range (empty sample chamber).

Besides the installed radiation sensors, which control the stability of the various radiation sources, and an attached mass spectrometer for analyzing the outgassing processes in the chamber, the construction of CIF allows adding other in-situ measurement systems to measure parameters that are of the user's interest. We are currently planning to develop an in-situ measurement system in order to determine changes in the optical properties of the samples caused by irradiation.

Configuration and geometry of the CIF (Figure 1)

The vacuum test chamber is connected to a lock chamber. The sample is mounted in a holder and will be transferred by a magnetically manipulator into the sample station in the center of the test chamber after vacuuming the lock chamber.

The beamline of protons and electrons, the optical path of the solar simulator and the light cone of the VUV-source are arranged in the same level and directed to the target with an angle of 30° to the solar simulator which is located in the middle. The Deuterium-UV-source is mounted above the solar simulator with an angle of 30° to the plane of the other sources.

The target mounting (Figure 2) allows a rotation of 30° in two directions to get an orthogonal relation in between the surface of the sample and the VUV-radiation respectively the beamline of particles.

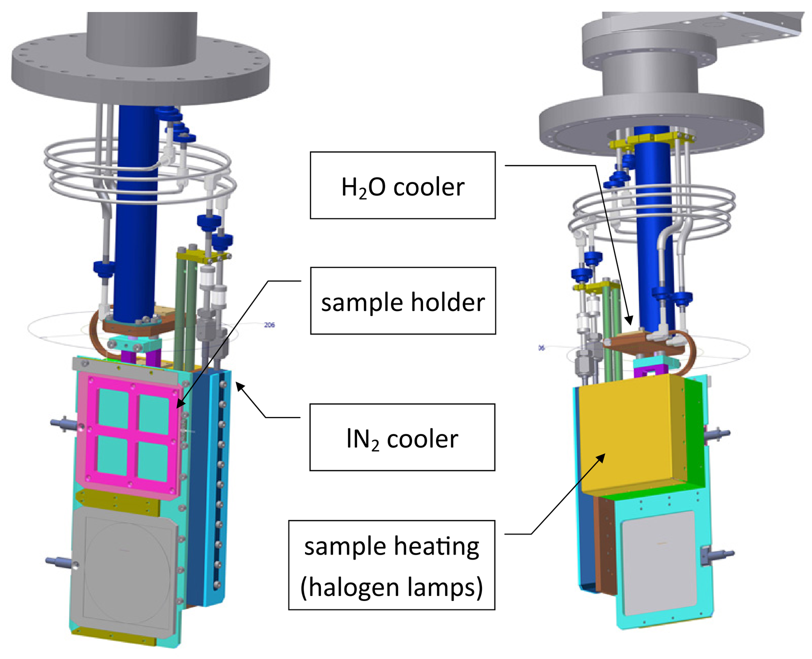

Figure 2: sample station in the center of the test chamber

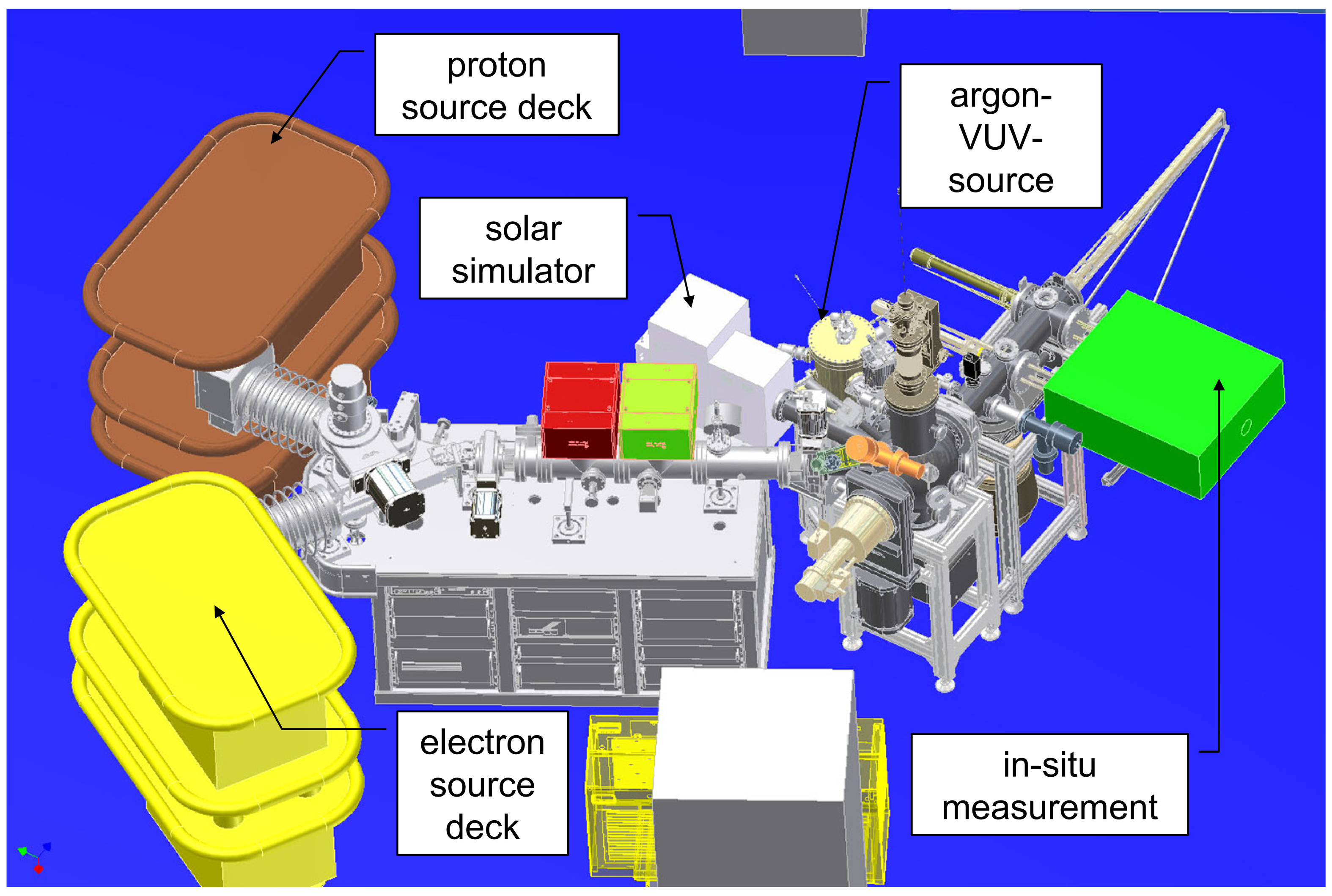

Figure 1: schematic overall view of the CIF configuration

Technical Parameters

Vacuum test chamber

Volume:	circa 33.5 l (400 mm diameter)
Irradiated Zone:	80 mm diameter
Vacuum:	$<10^{-8}$ mbar (without VUV)
	$<10^{-6}$ mbar (depending on VUV settings)

Light Sources

Solar Simulator:	250 to 2500 nm (5000 W/m², validated at DLR Berlin)
Deuterium UV Source:	112 to 400 nm (1.65 W/m², validated by PTB)
Argon-VUV-Source:	40 to 200 nm (50 mW/m², validated by PTB)

Proton and Electron Source

Current at lower Energy Range (1 to 10 keV):	1 to 100 nA
Current at higher Energy Range (10 to 100 keV):	0.1 to 100 µA

Target Thermal Conditioning

Heating:	Halogen Radiation (500W, 450K)
Cooling:	Liquid Nitrogen (LN2: 80 K)

Measurement and test engineering

In-situ Measurement of Reflectivity and Absorptance (medium-term strategy)

Quadrupole Mass Spectrometer (range: 0-512 amu)

Radiation, Temperature and Pressure Sensors

Faraday cup at the beam line of the proton / electron irradiation system and at the target in the test chamber (corner-cups)

The argon-gas-jet-VUV-simulator

Principle of operation [Verkhovtseva E.T. et al. 1997]

The radiation is produced by excited gas atoms which come to the ground state. The excitation occurs by electron bombardment (1keV energy) of a gas jet (98.5% Ar, 0.5% He, 1% Kr), which is injected by a nozzle from top of the VUV-chamber into the vacuum (figures 3 and 4). The main part of the gas load is pumped out through an intake port at the bottom of the chamber by a screw pump. The rest of the gas cloud is frozen out by two baffles, which are connected to both stages of the cold head from a commercial cryogenic pump. The alignment of the electron beam is approx. horizontal (+15°). The electrons which pass through the gas jet are caught by the collector at the opposite site of the gun. The intensity can be adjusted by varying the emission current of the electron source and the gas flow. Figure 5 illustrates the size and intensity of the spot qualitatively with different settings for the emission current in columns and for the gas flow in rows.

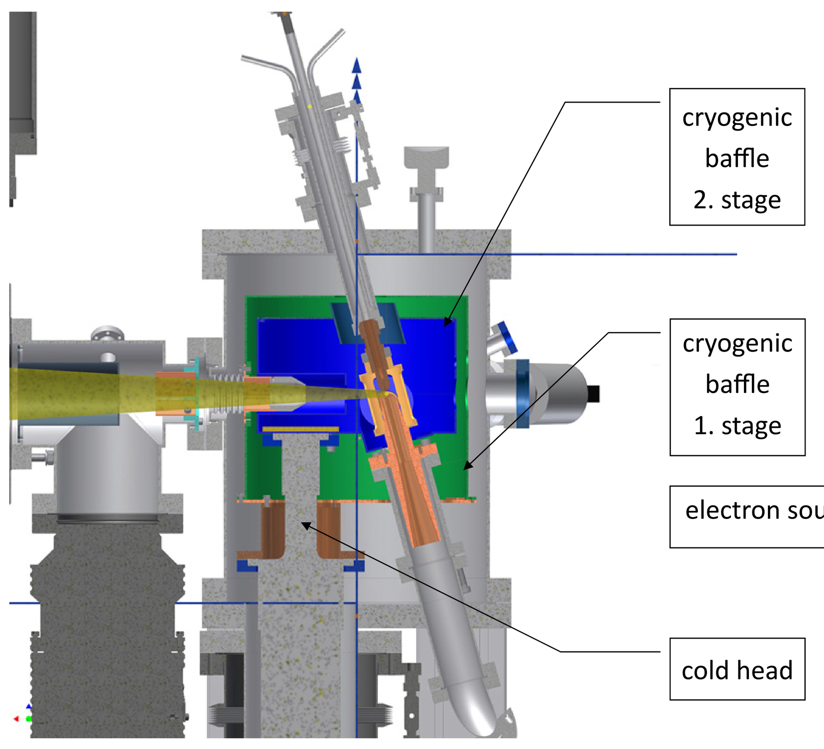

Figure 3: sectioning along the light cone (yellow)

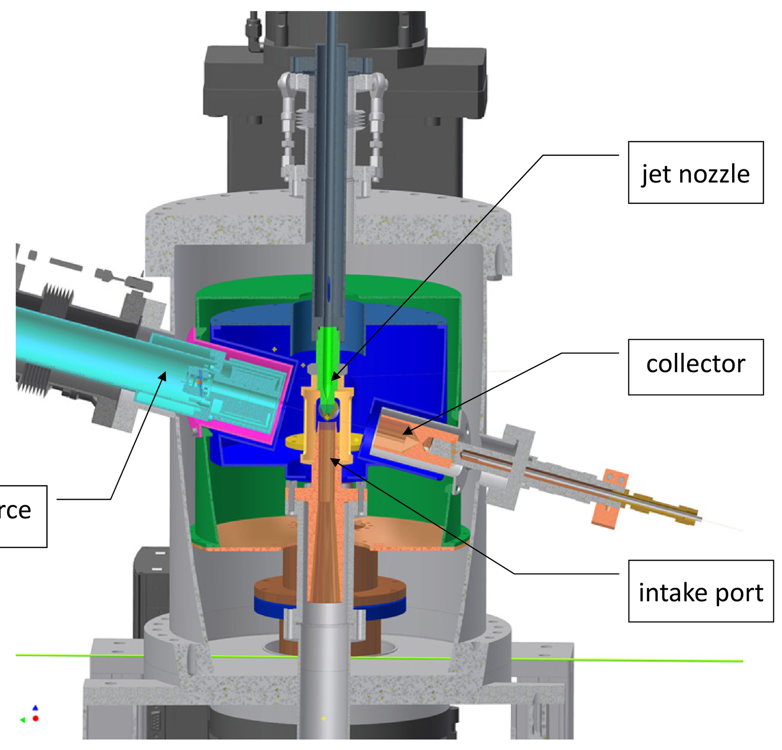

Figure 4: sectioning along the electron source (90° relating to Figure 3)

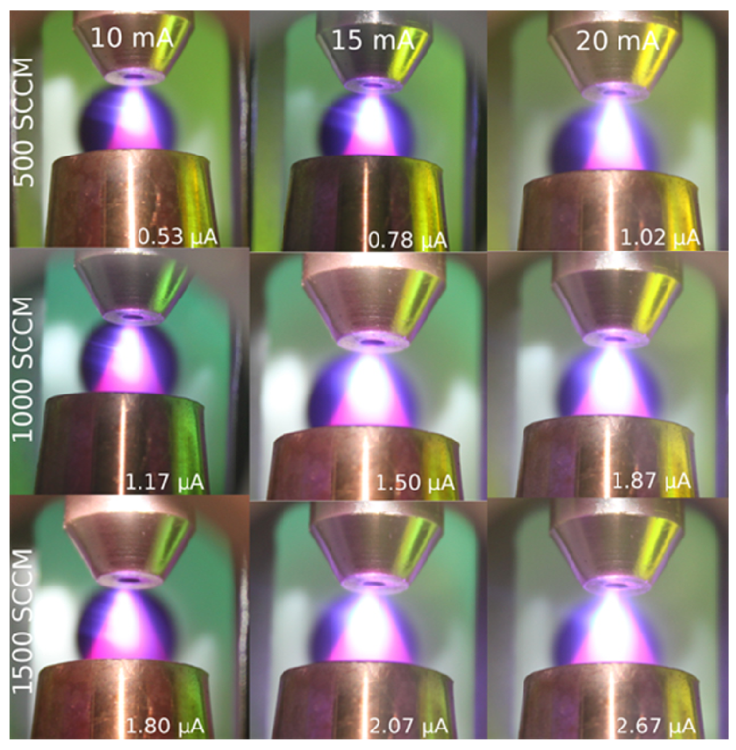

Figure 5: picture of the VUV-spot with different settings for the gas flow (rows) and the emission current (columns)

The spectras of electromagnetic radiation in comparison to zero air mass solar spectral irradiance

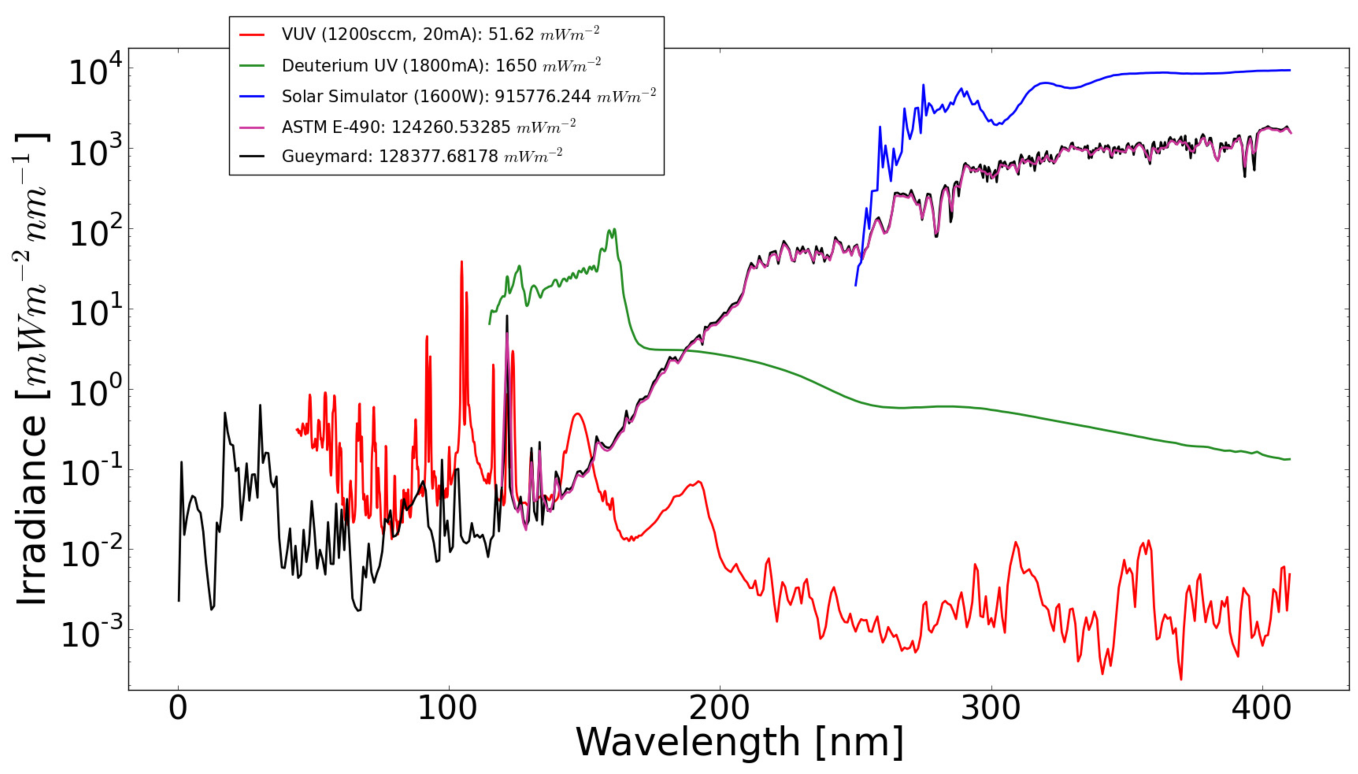

Figure 6: spectral irradiance of the argon-VUV-source, the deuterium lamp and the solar simulator in comparison to [ASTM E-490] and [Gueymard C.A.]

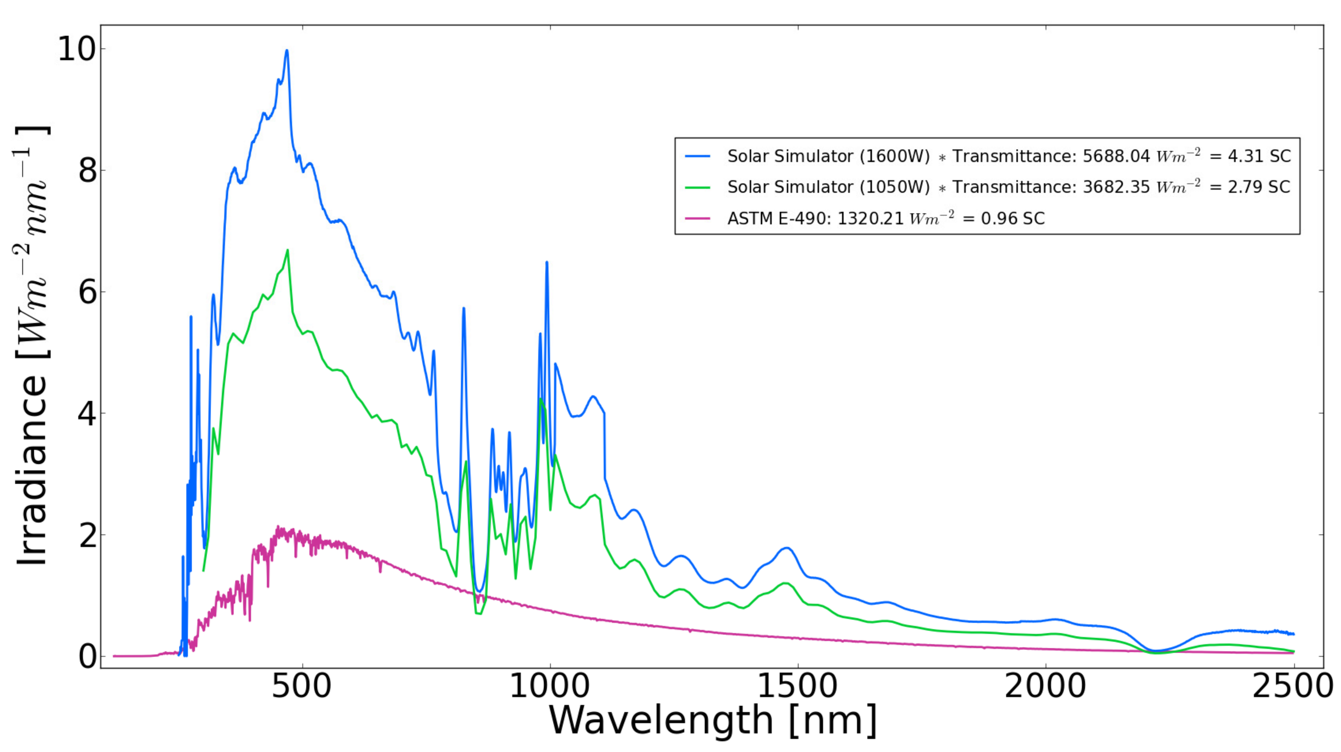

Figure 7: spectral irradiance of the solar simulator with different electrical power settings including the transmittance of the vacuum window in comparison to [ASTM E-490]

Present state and outlook

- **still commissioning after transfer to DLR Bremen**
- **procurement of a not ozone free Xenon lamp is in process to compensate the low intensity in the wavelength range between 180 and 250 nm**
- **first results with ex-situ measurements of thermo optical properties, in-situ will follow**

References

Verkhovtseva E.T., Yaremenko V.I., Telepnev, Lura F., Gas—jet simulator of solar VUV and soft X -ray radiation and irradiation effect on some material, Proceedings of the 7th International Symposium on Materials in Space Environment, Toulouse, France (1997)

ASTM E-490 Standard of Solar Constant and Zero Air Mass Solar Spectral Irradiance Tables

Gueymard C.A., The sun's total and spectral irradiance for solar energy applications and solar radiation models, Solar Energy, 76, 423-453, 2004

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