UT-VIV/PFC-Pyro

Task Title: APPLICATION OF A TRICOLOUR PYROREFLECTOMETER TO PLASMA FACING COMPONENTS IN-SITU INFRARED MONITORING

INTRODUCTION

The main subjects presented here are the following:

1) Comparison of an optical fibre probe equipped with a reflecting hemisphere which had been used for the measurements in 2004 with a new flat-headed one.
   Determination of the emissivities (that could not be measured in 2004) versus temperature by a direct method for the wavelength 1.3 µm and 1.55 µm.
2) Presentation of the development state of the dedicated solar set up DISCO and the tricolor pyroreflectometer for testing fusion material including a dedicated probe.
3) Preliminary tests for remote measurements on FE 200 and Tokamak

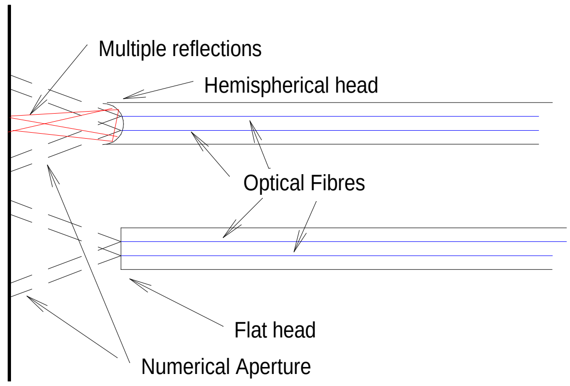


Figure 1: Scheme of the two kinds of probes equipped with optical fibres.

2005 ACTIVITIES

DEFINITION OF A PROBE ADAPTED TO DIRECT EMISSIVITY MEASUREMENTS

The experimental set up used is MEDIASE [2] as presented in the report A2 [1] and the sample tested (diameter. 25 mm, thick. 2 mm) is a pure W sample from Plansee Gmbh delivered by CEA [1].

These complementary tests are implemented for two reasons:

1) to compare results obtained with a probe equipped with a reflecting hemispherical probe -previous tests A2 - and a dedicated flat probe which avoids the interferences due to the multiple reflections (figure (1)).

2) to determine the emissivities at 1.3 and 1.55 µm through a direct method according to (1).

$$\varepsilon(T,\lambda,\theta) = L°(Tr(\lambda,\theta))/ L°(T,\lambda). \qquad (1)$$

Tr, is the measured radiance temperatures.

T is the true temperature of the sample that is assumed to be equal to the convergence temperature T* determined with a pyroreflectometry method [3] based on the introduction of a diffusivity factor η

$$\eta(T) = \rho^{0,\cap}(\lambda,T)/\rho^{0,0}(\lambda,T) \qquad (2)$$

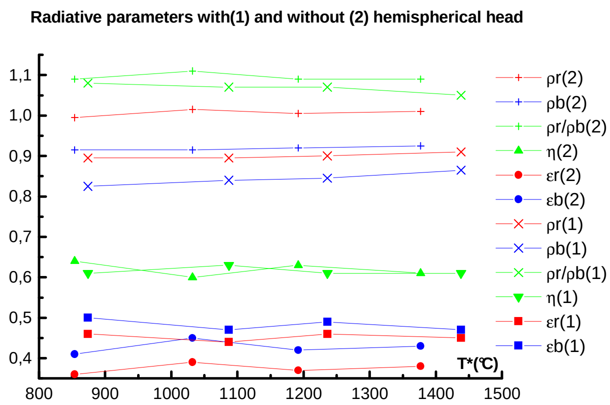


Figure 2: Results obtained with hemispherical (1) and with flat-headed(2) probe on a W sample
ρ normal normal reflectivity, ε normal emissivity,
η diffusivity factor
r corresponds to measurement at 1.55 µm, b to 1.3 µm.

The figure 2 shows the thermoradiative parameters measured with a two color pyroreflectometer: symbol (1) is used for the hemispherical probe measurements, (2) for the flat-headed probe measurements.
With the hemispherical head the emissivity is more important and the reflectivity is less important than with the flat head. This is the logical effect of the multiple reflections between the surface sample and the reflecting coating of the probe.
The ratio between reflectivities is almost constant. So the use of a flat or hemispherical probe is indifferent in this respect of the ratio.
Despite the fact that the diffusivity factors are equal in this case, only the flat probe gives good values for reflectivity and emissivity.

Table 1: Flat probe results on W during a thermal cycle

T* °C	Trr °C	Trb °C	ρr	ρb	εr	εb	η	ρr/ ρb
871	737	767	1.475	1.36	0.34	0.39	0.45	1.08
868	738	768	1.48	1.355	0.35	0.41	0.44	1.09
1050	883	921	1.48	1.355	0.37	0.42	0.43	1.09
1189	992	1036	1.495	1.37	0.37	0.43	0.42	1.09
1370	1120	1171	1.49	1.385	0.37	0.41	0.43	1.08
1625	1298	1357	1.565	1.48	0.36	0.4	0.41	1.06
1016	842	878	1.61	1.505	0.33	0.37	0.42	1.07

The table 1 summarises the results obtained with the flat probe configuration on the same sample as used for the measurements shown in figure 2 during one thermal cycle inside the solar furnace of the MEDIASE device.

Since W has specular reflection properties the normal reflectivities are larger than the value one.
The normal emissivities are in accordance with literature results [4].

DEDICATED APPARATUS DEVELOPMENT STATE

Two specific pieces of equipment have been developed in the frame of this task a tricolor pyroreflectometer and a dedicated vacuum vessel, the solar device DISCO.

The tricolor pyroreflectometer:

Components needed for the pyroreflectometer have been collected with difficulties and only now the realization of the apparatus is in the last phase with a large delay. Fortunately, the two color technique is enough to validate the method.

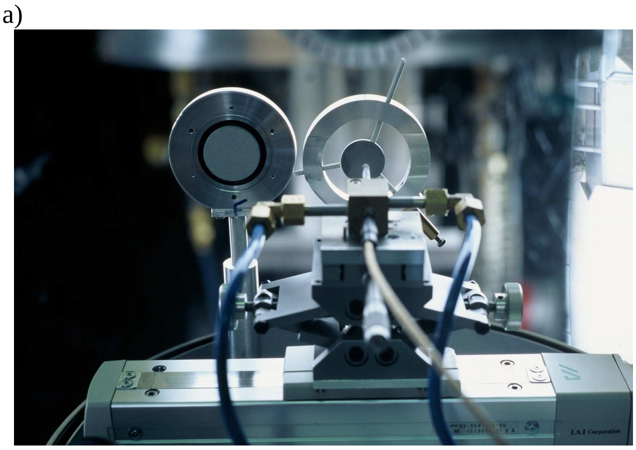
The dedicated solar device:DISCO (DIspositif Solaire de Caractérisation Optique i.e. Solar facility for Optical Characterization)

The specific vessel DISCO is finished and the photos of the figure 3 illustrate the set up.

The left one presents a detail with a water cooled probe – originally designed for the FE 200 test device, before it became obvious that another approach is needed (see section IV) - in front of a W sample back-face and next to it a reflectance reference for comparison measurements.

The photo (a) shows the vessel at the focus of a solar installation with a front window and a front-face of the sample.

a)



b)

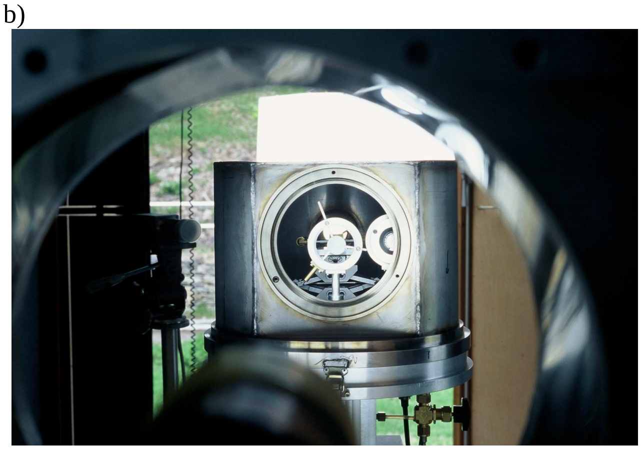


Figure 3: Photos of the dedicated vacuum vessel DISCO

Until now DISCO has been used for two kind of characterizations:

- to validate the measurement of the convergence temperature T* from an angular position different to the normal one.

- to measure the Bidirectionnal Reflection Distribution Function (BRDF) with a normal incident illumination.

i) Measurements under non-normal angles (preparation for FE 200)

The idea is to realize pyroreflectometric measurements on FE 200 in a configuration outlined in figure 4. In this case the location and orientation of the probe is angular out of the destroying electron's beam zone.

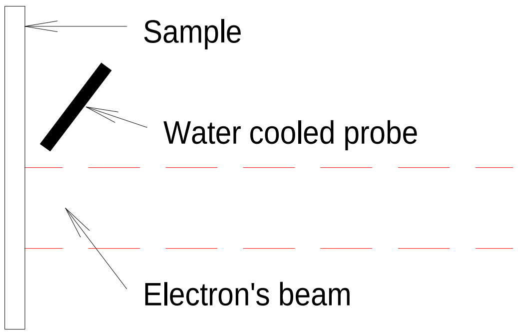


Figure 4: Scheme of a possible measurement configuration on FE 200

The table 2 summarises the results obtained when the axis of the probe is placed at different angles to the normal position of the sample.
The only measured parameters are the reflectivity, the others are simulated.
We can observe that the measured reflectivity decreases normally with the angle. However the ratios between the two reflectivity measurements rest the same within the accuracy of the measurement (better than 2%). By simulation we can estimate the convergence temperature T* and we conclude in accord with a theory [3]: the method is applicable because the ratio ρr/ ρb is constant.
30° is the limiting angle for this kind of measurement - for larger angles the measured signal is too low.

ii) BRDF determination for W samples

BRDF determination has been realized with a multi optical fibre probe. The observing fibres are located at 0, 10, 20, 30, 40, 50 and 60°. (figure 5)

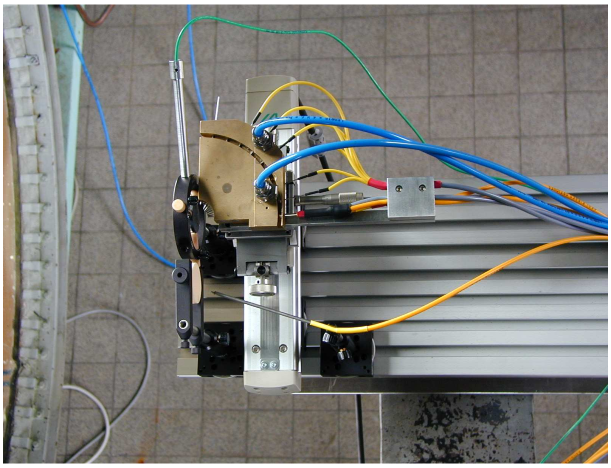


Figure 5: Photo of a BRDF measurement probe installed on DISCO

The results obtained show (figure.6) the specular properties of the W samples.

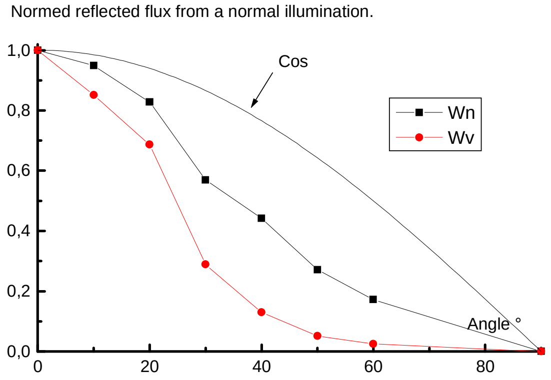


Figure.6: BRDF for W clean (Wn) and W glass-blasted (Wv)

PRELIMINARY WORK FOR REMOTE MEASUREMENTS.

The risks generated by the use of a water cooled probe on F200 near the electron's beam zone and the configuration for measurements in tokamaks directed the studies in the direction of the development of components and apparatus able to remote measurements from a distance of 1 m from the target.
To this purpose we have evaluated the measurement range of:

- a commercial monochromatic pyroreflectometer

- a commercial laser diode actually used in IMP pyroreflectometer systems.

i) Test of a commercial pyroreflectometer: Quantum Logic Model QL3600C-1A

Quantum Logic Model QL 3600C-1A is a device dedicated to measurements on diffuse samples. For samples with lambertian behavior, it delivers the temperature and the emissivity of the observed surface at a distance of 0.6 m and at the wavelength 0.9 µm.

The use of this kind of apparatus can be useful for the control of plasma facing components.
We have realized several measurements on different surfaces to evaluate the performance of the Quantum device for emissivity and indirectly reflectivity determination.

The table 3 shows all the results obtained.

The Quantum pyrometer appears adapted to measurements on diffuse surfaces. The use of its technology for the ITER configuration and the convergence method need improvement in optics and signal acquisition and treatment. It needs particularly the adjunction of a second wavelength.

Table 2: R esults for different angular measurements on W

Angle°	ρr	ρb	ρr/ ρb	εr	εb	η	T* °C
0	1.51	1.41	1.07	0.32	0.37	0.45	1000
15	1.15	1.08	1.06	0.31	0.35	0.60	1006
30	0.22	0.20	1.1	0.36	0.42	2.91	980

Table 3: Results obtained with Quantum pyroreflectometer
(Diffuse samples are lambertian reflection standards with reflectivity values as indicated)

Sample	Diffuse 98	Diffuse 75	Diffuse 50	Diffuse 20	Diffuse 10	Cu blasted	Cu polished	W clean	W oxidized
ε(0.9 µm)	0.5	0.27	0.52	0.80	0.89	0.20	0.33	Out of scale	0.50

ii) Distance with a commercial laser diode

A laser diode (characteristics: λ =0.830µm and power =1 W) has been tested without focalisation optic in the actual IMP configuration probe.
The reflected signal obtained at 0.60 m is about 80 mv and about 40 mV at 1 m.

The laser diodes of the present version of pyroreflectometer used at Odeillo (λ 1.3 µm and 1.55 µm) have a power of less than 100 mW. Consequently the improvement of the tricolor pyroreflectomer to extend its distance of observation needs the development of a dedicated optic and some preliminary measurement tests.

CONCLUSIONS

Pyroreflectometry method, probe and apparatus were tested on PROMES facilities to be improved for measurements on CEA reactors and facilities as FE200 or Tokamaks:

- A probe with a ‘flat head’ has been compared to an ‘hemispherical head’. Only the flat probe has allowed to determine correctly the emissivities at 1.3 µm and 1.55 µm for W sample delivered by CEA.

- The device DISCO has been used to validate pyroreflectrometric measurements with an orientation of the probe in a direction different than the normal (to the surface) position.

- This configuration can be applicable to FE 200 but unfortunately the risks of damage from the electron’s beam impedes real tests. Complementary measurements have been realized to determine the B.R.D.F. of W samples.

- Preliminary tests have been conducted for remote measurements. Two technical solutions appear:

- An improvement of a commercial solution.

- A design and a realization of an optical head adapted to the IMP fibre optical pyroreflectometer.

The second solution offers the advantage to continue with the same architecture and to benefit of the laboratory developed software and methods.

If the power of the presently used laser diode should not be enough, it may become necessary to change the used wavelength. All these technologic improvements and tests are the challenge for 2006.

REFERENCES

[2] M. Balat-Pichelin, D. Hernandez ‘Concentrated Solar Energy as a diagnostic tool to study materials under extreme conditions’ Journal of Solar Energy Engineering Vol. 124 pp 215-222 august 2002

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[3] D. Hernandez ‘A new concept to determine the true temperature of opaque materials using a tricolor pyroreflectometer’, Review of Scientific Instruments, Vol 76, 024904, pp1-7, 2005

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