A Proposed In-Vessel Calibration Light Source for the Joint European Torus

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** See the appendix of M.L. Watkins, et al., Fusion Energy 2006 (Proc. 21st Int. Conf. Chengdu, 2006) IAEA, (2006).*

ABSTRACT

An in-vessel calibration light source (ICLS) is proposed for use during extended shutdown periods of the Joint European Torus (JET). The ICLS is primarily a 12 inch integrating sphere (4 inch opening) with 4 lamps (of known luminance), which can be positioned inside the JET vacuum vessel via the Remote-Handling Arm (RHA). This will facilitate the *in-situ* calibration of optical diagnostics, which rely on absolute light intensity measurements currently made when the diagnostics are removed from JET. The ICLS could ultimately reduce/remove the mechanical stresses associated with the repositioning of diagnostics for calibration purposes. At least 10 diagnostic systems could benefit from the ICLS; in some instances the ICLS provides the only viable absolute-calibration strategy. Moreover, the ICLS will be a broad-spectrum "white" light source, enabling intensity calibrations at all visible wavelengths. A secondary benefit of the ICLS is in its use as an illumination source for making measurements of the reflectance (over a broad spectral range, and at multiple angles) from the tiles lining the JET vacuum vessel.

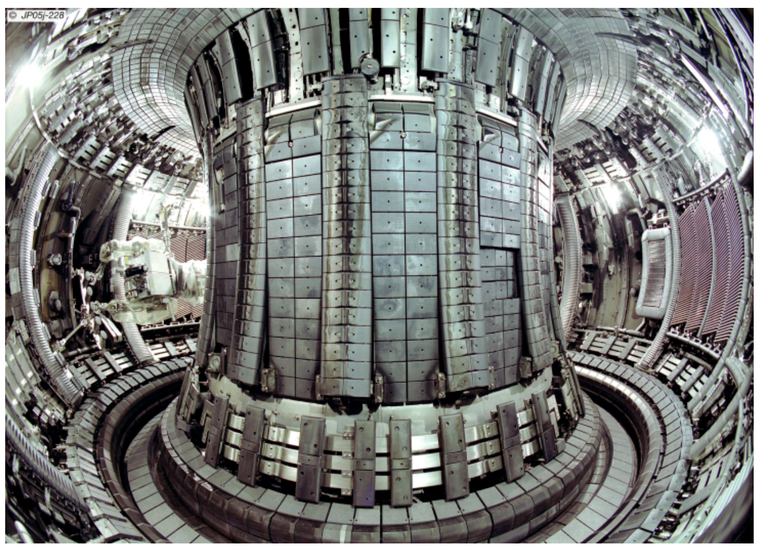

Figure 1: Internal view of JET with the RHA & MASCOT deployed.

INTEGRATING SPHERE CALIBRATED LIGHT SOURCES [1,2]

- Specifying the integrating sphere: L_s = average radiance at exit port
  - ϕ_i = total radiant input flux (from lamp)
  - $A_s = 4\pi r^2$ = sphere surface area
  - ρ = sphere wall reflectance
  - f_j = port fraction

$$L_s = \frac{\rho\phi_i}{\pi A_s\left(1-\rho\left(1-f_j\right)\right)}$$

- Desire large port opening for ease of diagnostic calibration
  - Exit port area should not exceed ~5% of the sphere surface area
- Overall sphere size limited by torus entry/exit constraints and stable lifting restrictions
- Lamp arrangement
  - "Externally mounted" lamps couple ~40% of light from a similar "internally mounted" lamp
  - A variable attenuator has an additional ~72% coupling efficiency

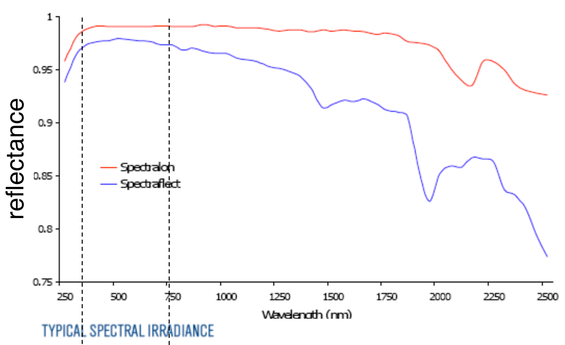

Figure 2: (a) The spectral reflectance of commercially available integrating sphere coatings, and (b) a typical spectral irradiance curve for a Tungsten-Halogen lamp. The visible range of light is shown for comparison.

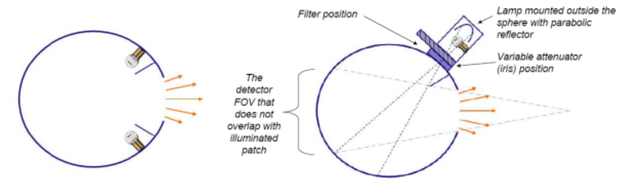

Figure 3: Schematic showing the difference between (a) internally mounted and (b) externally mounted calibration lamps for an integrating sphere.

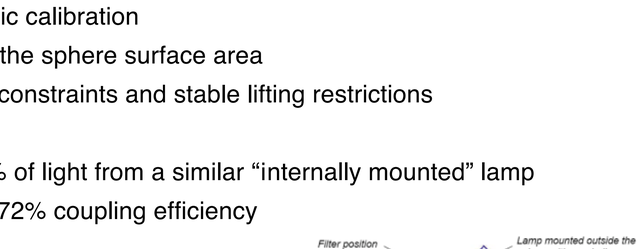

Figure 4: Manufacturer supplied (a) photograph and (b) line drawings of a typical 12-inch integration sphere with 2 lamps, including rack-mount power supplies and control hardware.

- Specifications of the proposed In-Vessel Calibration Light Source (ICLS)
  - 12-inch integrating sphere with 4-inch exit port
  - Coated with Spectraflect
  - 4 ports for calibrated lamps
    - 2x externally mounted 100 W Tungsten-Halogen bulb
      - ~75 mW/cm²/sr/μm at 600 nm (similar to divertor intensity)
    - 2x internally mounted 5 W Tungsten-Halogen bulb
      - ~3 mW/cm²/sr/μm at 600 nm (similar to plasma limb intensity)
    - 2000 hour lamp lifetime (recommended recalibration after 10% of lifetime)
      - Cross calibration between lamp sets to extend operating lifetime
  - 20 m cabling so that only ICLS "head" is brought inside JET vacuum vessel

JET REMOTE HANDLING ARM [3]

- JET in-vessel environment posses a danger due to radiation and Be contamination.
- Long in-vessel dwell times of the ICLS require the use of the JET RHA and MASCOT.
- ~20 pound ICLS "head" can be easily grasped and stably held with standard RHA handles.
- ICLS is remotely operated via PC (Timbuktu) over the JET intranet.

Figure 3.2-2 : JET RH Control Room

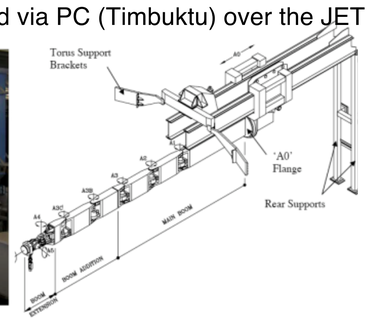

Figure 3.3-1 : Octant 5 Boom (Enclosure not shown)

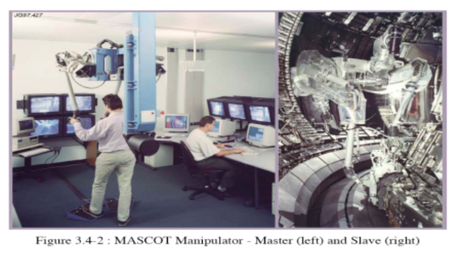

Figure 3.4-2 : MASCOT Manipulator - Master (left) and Slave (right)

Figure 5: Figures from Ref. 3, showing the JET Remote Handling facilities in operation.

DIAGNOSTIC CALIBRATIONS

- ~10 diagnostic systems on JET will benefit from *in-situ* calibration using the ICLS
- ~120 lamp-hours are needed for a "full calibration:" post-campaign and pre-campaign
- Next opportunity for deployment of the ICLS is during the 2009/10 ITER-like Wall intervention

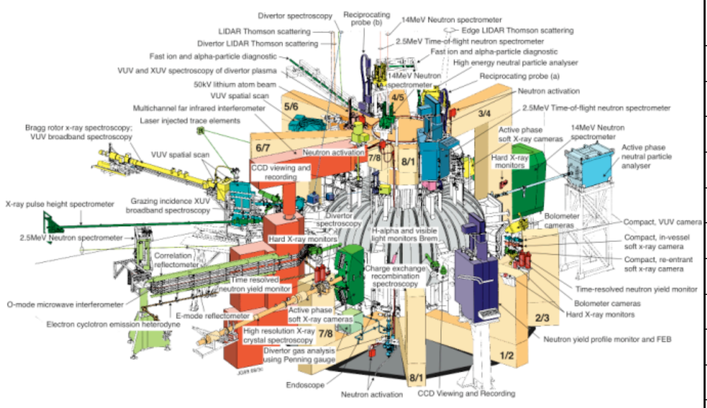

Figure 6: Overview of JET diagnostics.

Diagnostic	Description	R.O.	Ports	Factors	Shifts	Lamp hours
KS3	Vis. Spec.	M. Stamp	3	4-6 lamp pos.	12-16	12-16
KS4	Vert. CXS	A. Meigs	1	Post, var l,pre.	4	16
KS5	Tor. CXS	C. Giroud	2	Post, var l,pre.	4	24
KS7	Pol. CXS	Y. Andrew	3	post, pre.	6	18
KS8	Zmn. Spec.	M. Stamp	1	post, pre.	2	4
KS9	MSE Spec.	N. Hawkes	1	Rotary polarizer	2	4
KT1	Scan. VUV	K. Lawson	2	3-5 rot. mir. pos.	12-20	12-20
KE11	HRTS	M. Beurskens	1	post, pre.	2	4
KT3	Div. Spec.	A. Meigs	1	var l	4	16
KT4	VUV Spec.	I. Coffey	1	post, pre.	2	2
KT7	VUV Spec.	I. Coffey	1	post, pre.	2	2

Table 1: Summary of JET diagnostic usage of the ICLS: Total: 52-64 shifts, 114-126 lamp hours.

TILE REFLECTANCE MEASUREMENTS [4]

- The reflectance of the JET tiles is an important parameter in modelling light reflections.
- The ICLS can be used to illuminate new Be, W, and CFC tiles during the ILW intervention.
- Can be repeated in subsequent openings to ascertain the effect of plasma operation.

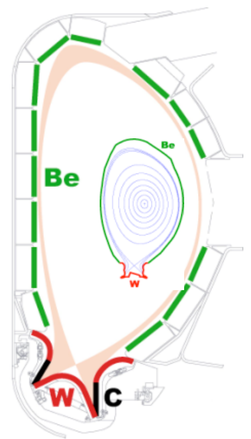

Figure 7: Location of tile types in ITER and JET.

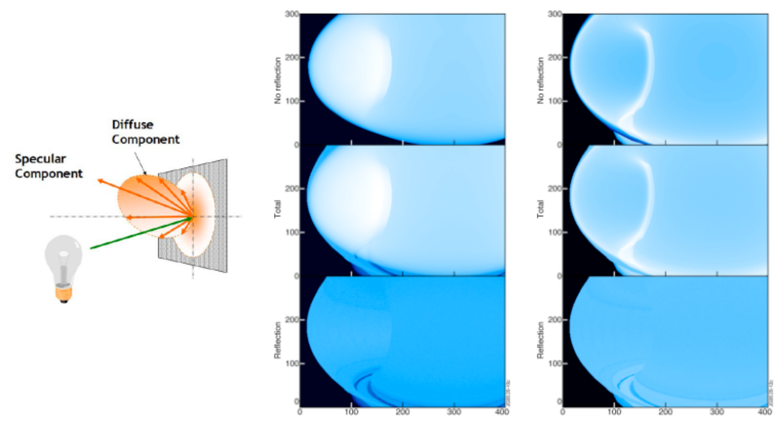

Figure 8: Modeling of total (specular + diffuse) reflected light from JET tiles as would be seen by a simulated JET imaging diagnostic due to bremstrahlung and to an edge-peaked source of light. See Ref [4] for more detail.

SUMMARY

- An in-vessel calibration light source (ICLS) has been proposed for JET to facilitate the *in-situ* calibration of visible spectroscopy diagnostics.
- It is intended that the ICLS would be deployed during the 2009/10 ITER-like Wall intervention.

REPRINTS

Electronic copy available at: http://sprott.physics.wisc.edu/biewer/HTPD08poster.pdf

ACKNOWLEDGEMENTS

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REFERENCES

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[3] D. Locke, "JET Remote Handling Requirements - Remote Handling Equipment," CD/S/J408, U.K.A.E.A. Culham Science Center, Abingdon, UK OX14 3DB (2007).

[4] K.-D. Zastrow, S.R. Keatings, M. O'Mullane, G. de Temmerman, Poster N27 in this session, HTPD 2008.