Status and Development of Globus-M Diagnostics.

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The purpose of this report is to describe the status and the near term plans for diagnosing the Globus-M tokamak [1] (major radius $R=0.36$ m, minor radius $a=0.24$ m, aspect ratio $A=R/a=1.5$, plasma current up to 0.5 MA in toroidal magnetic field up to 0.6 T on axis).

Plasma parameter	Diagnostics	Phase	Lead
Plasma column position and shape	Flux loops	1	Ioffe
	Rogovski coils	1	Ioffe
	B_p coils	1	Ioffe
	Slow Plasma TV	1	Ioffe
	Fast plasma TV	2	Ioffe
Basic	Diamagnetic loops	1	Ioffe
	1 mm interferometer	1	Ioffe
	0.3 mm interferometer	2	Ioffe-Kurchatov
	Soft X-ray detector	1	Ioffe
	Bolometers	2	SPTU
Profile	Thomson scattering	2	Ioffe-LOMO
	Radar reflectometer	2	TRINITI
	CHERS	3	Ioffe
	MSE	3	Ioffe
	NPA	3	Ioffe
Impurity	Visible spectroscopy	1	Ioffe
	VUV spectroscopy	3	Ioffe
MHD	Mirnov coils	2	Efremov
	SXR tomography	2	VNIIEF
	USXR spectroscopy	3	Ioffe-FOM
Edge/Divertor	Langmuir probes	3	Ioffe
	Laser induced photo ionization	3	Ioffe
Fast Ions	Neutral particle analyzer	2	Ioffe
Runaways	Radiometer	1	Ioffe
	HXR spectroscopy	1	Ioffe

Table.1 *Globus-M diagnostics currently installed or under development, the phasing of this development and the lead institution.*

All diagnostics, according to the phase of readiness and the institution responsible for their development, are listed in table 1. The first phase is the diagnostics that are currently in use, second phase – under construction (will start measurements in 2001-2002) and third phase – under development or discussion.

The plasma current, shape and position is determined by means of a set of flux loops (2 in-vessel and 10 external), magnetic probes (6 in-vessel 1D and 43 external 2D) and Rogowski coils (1 in-vessel and 2 external). The signals of 2D magnetic probes were processed by EFIT code for reconstruction of the plasma outer magnetic surface shape. Two sets of in-vessel Mirnov coils and magnetic probes for the plasma shape reconstruction are under design.

Currently in use is visible spectroscopy, HXR - spectroscopy, SXR filter spectrometer, slow CCD video camera, and diamagnetic measurements by two external loops.

Plasma density is monitored with 1-mm microwave interferometer by 3 vertical channels. For further density measurements one horizontal channel is developed. Also O.337mm HCN laser interferometer is under construction now.

Thomson scattering will be the leading diagnostics for detailed electron temperature and density profile measurements in Globus-M. The tangential view plasma probing has been chosen to enable the recording of $T_{e,}$ N_e distribution over the major radius at mid-plane (see fig. 1). The probing laser represents a Q-switched neodymium glass laser capable of pulse train generation up to 20 pulses with variable, controlled intervals between them (down to 0.3ms). Up to 18 J energy per a pulse in ~0.1mrad full angle divergence is expected. The laser produced by LOMO is currently being installed.

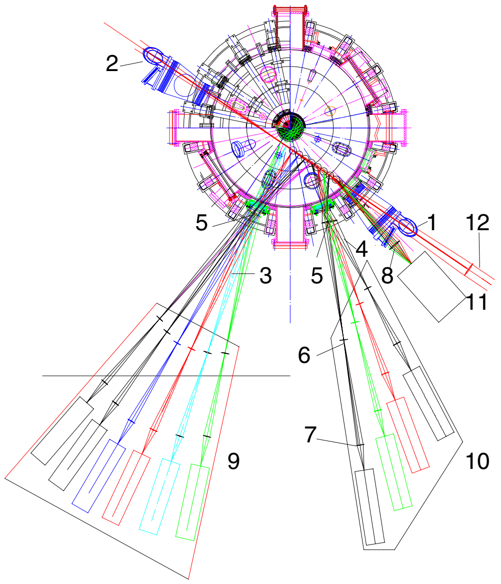

Figure 1. *1,2 –entry and exit ducts, 3,4- primary viewing fans, 5- collecting lens together with optical wedge, 6,7- field and imaging lenses, 8- backscattering collecting lenses,9,10,11- polychromator set, 12- laser beam*

The laser beam is directed through the machine on the horizontal mid-plane at $R_{tan=}$ 14 cm. The scattered light will be observed through two 16 cm and one 6 cm windows by means of three F/7 collecting lenses and the array of interference filter and grating spectrometers adapted to electron temperature range from 50eV to 2000eV. The detection system makes maximum usage of high gathering power interference filter polychromator model GAPB 1064-4-1K described elsewhere [2]. A lower order blaze high dispersion grating spectrometers [3] based on use of uncustomary large diffraction angles approaching 80° has been designed as an alternative. The total number of spatial points will be 10, but the diagnostic commissioning will begin from a few spatial locations with scattering sampling length of 20 mm, which are spread over 75% of the major radius. The density detection lower limit of $10^{17}m^{-3}$ is expected due to a powerful laser output, high gathering power of the spectrometers and low noise solid-state detectors.

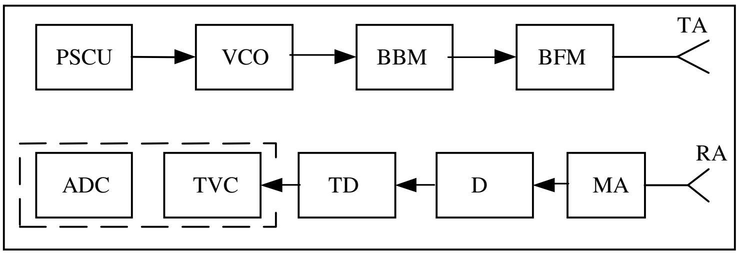

Figure 2. *The block-scheme of channels of a SPRR. PSCU – power supply and control, VCO – varactor controlled oscillator, BBM – block of the broadband modulator, BFM – block of the frequency multiplier, TA – transmitting antenna, RA – receiving antenna, MA – microwave amplifier, D – detector with the pulse preamplifier, TD – time discriminator, TVC – time-to-voltage converter, ADC – analog-to-digital converter*

The scanning pulse radar reflectometer suits to a detailed electron density profile measurements in the range of $(0.45\text{-}4.5)x10^{19}m^{-3}$ with a relatively good temporal resolution (10-20 ms per profile). To cover the mentioned density range, the fast scanning channel in the frequency range of 26-40 GHz and three supplementary channels with fixed frequencies, settled at ~19, 50 and 60 GHz are used. The scheme of the channel with frequency scanning is shown in Fig. 2. Hyper abrupt varactor-tuned oscillator (VCO) VO3263P/00, Sivers Ima, in the frequency range of 13-20 GHz followed by broadband modulator (BBM) SW-2181-1, American Microwave Corp., and full-band active frequency doubler (BFM), AKa-2XW, Spacek Labs Inc. provides the peak microwave output power of about 200 mW. In order to get sufficient S/N ratio and spatial resolution of about 1 cm, the low-noise wide band microwave amplifier (MA), SLK-25-5W Spacek Labs Inc. is used. A pilot reflectometer channel at 60GHz was successfully tested on the T-11MU tokamak.

The CCD camera with enhanced dynamic range was manufactured for observation of transient phenomena of plasma discharge development. The device is based on the common interline transfer CCD chip ICX39BLA (752*582 pixels) and photodiode (PD) array (4x4) specially developed at the Ioffe Institute according to local epitaxy technique. Light sensitive areas of both PD array operating as an “exposure meter array” and CCD are optically matched (see Fig. 3). At each instant time the photodiode signal magnitude rates the camera exposure time to fit it to the CCD dynamic range. The controlling photodiode or diode group size essentially exceeds one CCD pixel size and gets sufficient information during time period negligible as compared to demanded CCD exposure time. Therefore, unlike the majority of modern devices based on automatic exposure control the model allows recording plasma images with an exposure time control according to luminosity of image fragment under study. A signal of either one or several photodiodes of PD array specified by a commutator as an optional image fragment is used to determine required exposure time.

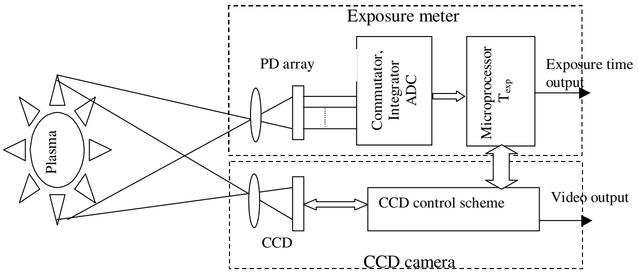

Figure 3. *Plasma monitoring system with automatic exposure control.*

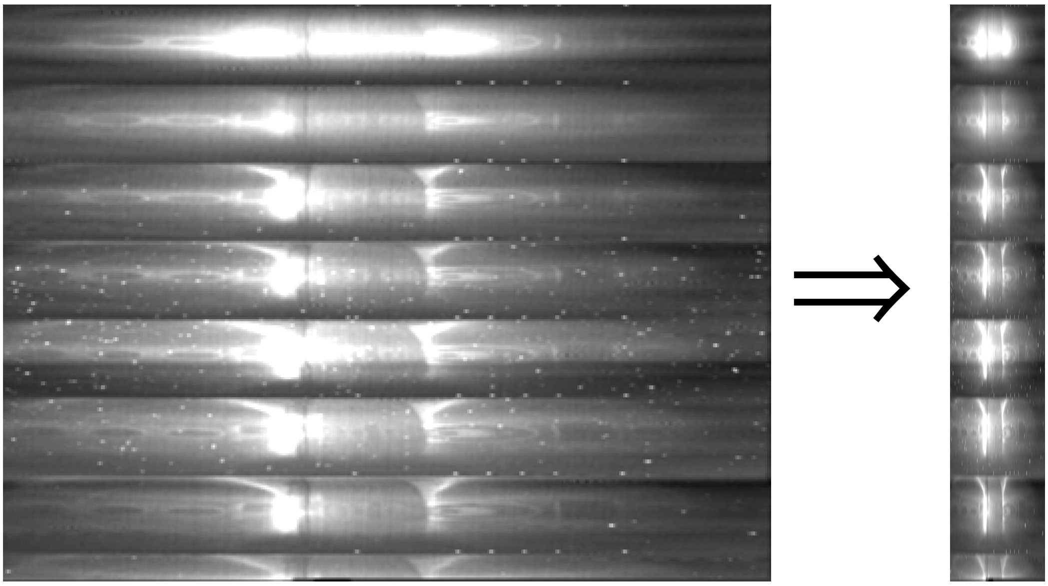

Figure 4. *The images of plasma and contraction fragments of Globus-M tokamak with spatial resolution 39x700 pixels temporary resolution 2.5msec. The light dots resulted from secondary X-ray radiation with 0.1-15keV energy.*

To test the real dynamic range along with CCD camera performance, the experiments under exposure control and 400Hz acceleration mode were conducted. The CCD camera accomplished with space exposure control system had been used for plasma monitoring in experiments on spherical tokamak Globus-M. The experimental plasma images with repetition rate of 400Hz are shown in Fig. 4. A high speed CCD video camera (2000-4000 fr/s) on the base of developed in-frame exposure control principle is being constructed.

SXR pinhole cameras. Two SXR cameras integrated to horizontal and vertical ports are being constructed now (see Fig. 5). The top and side view cameras are equipped with three individual 16-channel detector arrays with build-in preamplifiers. Each array consists of separate diodes of 3x10mm chip dimension with 2x9mm sensitive area. The diode arrays are specially manufactured for diagnostic setup. The build-in amplifiers are capable of high-speed operation (up to several MHz). The compact design of build-in amplifiers permits to avoid the empty space over the imaging area. The changeable filters are located in front of diode arrays. The technology of manufacture of special rubber drives for a movement of camera in vacuum has been developed. Because of the access difficulties the in-situ detector calibrating is worked out. The data acquisition system has been designed and is under construction now. It consists of 96 pick-up channels for SXR plasma signals and 4 channels in addition for calibrating source monitoring.

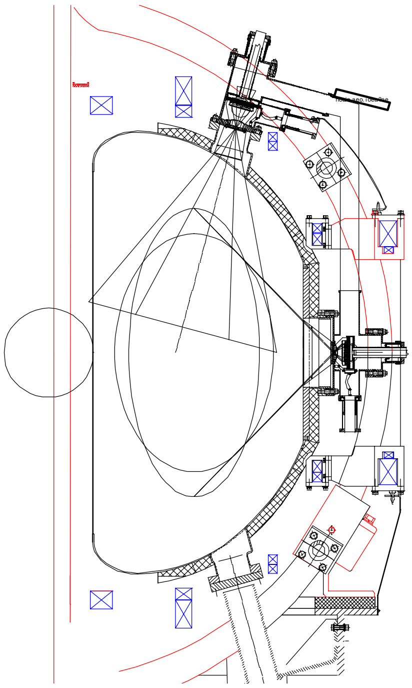

Figure 5. *Two SXR cameras integrated to horizontal and vertical ports*

Other following diagnostics should start measurements to the end of the year: 4 channel pyroelectric bolometer (is ready for installation), the set of 10 in-vessel Mirnov coils and the NPA with E||B dispersion (are being constructed). Other planned diagnostics such as CHERS, VUV spectroscopy, TV Thomson scattering, laser induced photo ionization [4] and multi-layer SXR filters are under discussion.

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