NUKLEONIKA 2001;46(Supplement 1):S99–S101

Multichannel calorimeters for measurement of flows of X-ray radiation in the range from 10 up to 200 keV

Valentin P. Vinogradov

Abstract An 8-channel calorimeter was developed and applied to the Plasma focus facility (PF) with flat geometry of electrodes (Filippov type) for the measurements of a hard X-ray (HXR) radiation yield and its spectral distribution. The calorimeter measures the time-integrated HXR flux for one shot of the PF facility without any additional calibrations. The sensitivity $\sim 10^{-4}$ J/cm^2 was achieved.

Key words calorimeter • hard X-ray • plasma focus

Introduction

The hard X-ray (HXR) yield emitted from the PF facility is measured usually with dose meters such as thermo-luminiscent detectors, for example. The total energy of X-ray flux can be calculated in this case only if you know spectral distribution of the radiation [1]. The calorimetric method with a full absorption of radiation in the target allows to measure the HXR yield directly without any additional calibrations. A suitable target for quanta with energy of tenths and hundreds keV must be rather thick and heavy. We have decided to split the thick target to the small ones and to measure the energy absorbed by each one separately.

The basis of the instrument design

In the offered method of hard X-rays measurements several thin metal disks, located one after another, are used as targets absorbing radiation in various ranges of energy of quantum. Each target (except for the last one) is used as a filter for the targets located behind it. Only one diagnostic window is needed for this multichannel calorimeter for the reason of positioning targets in the consecutive order.

The targets are made of various elements and located one after another in an ascending order of the atomic number. In this case, it is possible to achieve more sharp separation of the spectral ranges and maximum sensitivity at the expense of choice of an optimum thickness of each target. The selection of suitable element and thickness for each target allows to use them in a range of energy of quanta close (but upper) to K-jump, where the cross-section of photoabsorption is essential more, than that of elastic and inelastic scattering. It allows to neglect the influence of the

V. P. Vinogradov
RRC "Kurchatov Institute",
Kurchatov sq. 1, Moscow, 123182, Russia,
Tel.: +7095/ 1967622, Fax: +7095/ 9430073,
e-mail: vpv@nfi.kiae.ru

Received: 28 November, Accepted: 10 January 2001

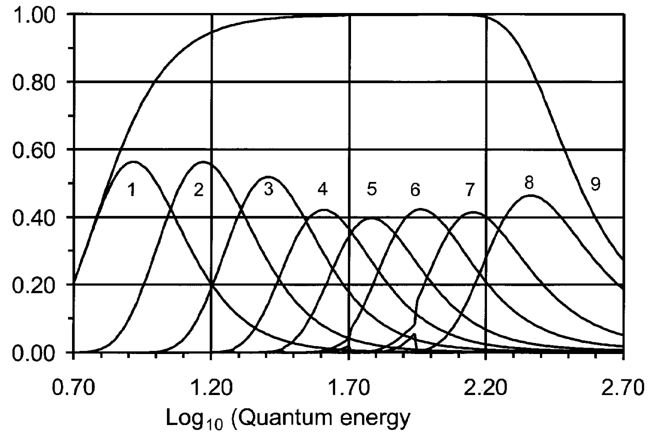

Fig. 1. Absorption of X-rays by the targets: 1 – Al 0.14 mm; 2 – Ti 0.1 mm; 3 – Cu 0.1 mm; 4 – Nb 0.12 mm; 5 – Sn 0.25 mm; 6 – Gd 0.41 mm; 7 – Pb 0.485 mm; 8 – Pb 2.01 mm; 9 – total absorption.

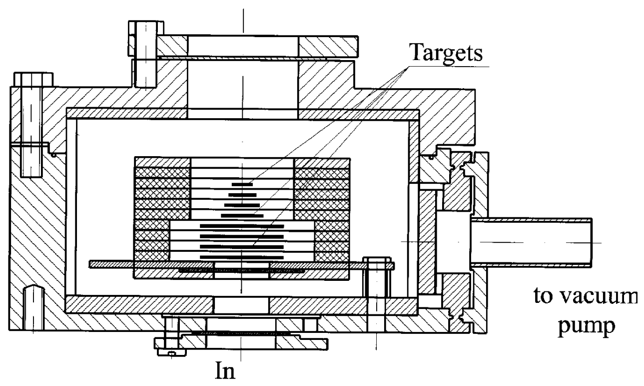

Fig. 2. Construction of the calorimeter.

scattered quanta that considerably simplifies calculations. The radiation is absorbed in the 8 targets of thickness from 0.1 up to 1 mm, made of various metals from Al up to Pb. This set of targets is indicated in Table 1.

The curves in Fig. 1 show the parts of full X-ray flux absorbed by each target. The total curve of X-rays absorption by a full set of targets is shown too. It is visible that the total curve of absorption of radiation is not lowered below 0.8 in the range from 10 up to 200 keV and all the complete set of targets works as a set of band-pass filters.

The construction

The construction of the instrument is shown in Fig. 2. The changes of temperature of the targets are measured with the help of thermocouples. The thermocouples are made by welding Ni-Cr and Cu-Ni wires (0.05 mm diameter and 1 cm length) to pieces of an 1×1 mm^2 Ni foil by thickness 0.04 mm. The group of 8 such thermocouples are pasted to the targets through an insulating layer of capacitor paper by a thickness of 0.01 mm. The thermal resistance between the targets and thermocouples is much less than that for the thermocouple wires. Therefore, the temperature of the "hot" end of the thermocouple practically is equal to the temperature of the target. The "cold" ends of thermocouples are located in the cartridge, enclosing the set of targets. To avoid distortions of the indications, the first 4 "light" targets, at the expense of an absorption of X-rays in the wires of thermocouples, are made as disks of diameter (20 mm) greater than the input window of the calorimeter, and the thermocouples are pasted on the rims of disks outside of the stream of X-rays. The "heavy" targets (5–8) have a diameter smaller than the window of the calorimeter and each following is smaller than the proceeding one (12, 10, 8 and 6 mm). Thus, all targets are in "shadows" of the proceeding ones.

The instrument is constructed in such away that the time of cooling of all the targets was rather long. The following reasons for this are:

1. Large warm-up time of the last targets (~0.1 s for #8).
2. Large level of electromagnetic disturbances forced us to transfer the moment of the measurements to later time, when all oscillatory processes in the installation fade away.
3. Very small level of the signal (10^{-7}–10^{-6} V) forced us to make amplifying tracts with the very narrow (~1 Hz) frequency passband and time of measurements of the signal ~1 s.

The following measures were accepted for the magnification of cooling time of the targets and diminution the influence of disturbances:

1. The case of the calorimeter is evacuated up to a vacuum of ~0.1 Pa.
2. Wires of a minimum accessible to us diameter are used for the thermocouples.
3. Thick (~1 cm) walls of the case and the connection of its details with the Indium sealing were made to maintain isothermal conditions in the internal space of the case

Table 1. Parameters of the targets.

Number of target	1	2	3	4	5	6	7	8
Element	Al	Ti	Cu	Nb	Sn	Gd	Pb	Pb
Atomic number	13	22	29	41	50	64	82	82
K-jump (keV)	1.56	4.97	8.98	19.0	29.2	50.2	88.0	88.0
Thickness (mm)	0.14	0.10	0.10	0.12	0.25	0.41	0.48	2.01
Energy range (keV)	6–15	10–25	17–43	28–68	41–100	62–157	95–250	150–440
Diameter (mm)	20	20	20	20	12	10	8	6
Time of cooling through thermocouple wires (s)	320	220	330	260	380	170	100	240
Time of cooling by radiation (as black body) (s)	28	19	29	22	92	61	57	236
Time of cooling by the expense of the residual air at 0.1 Pa	1200	700	1060	830	3400	2200	2000	8600

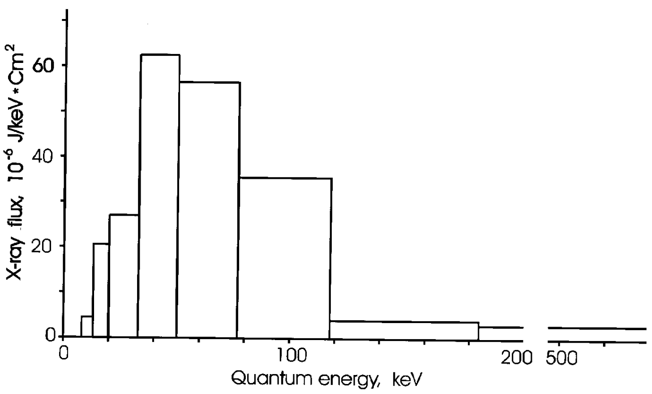

Fig. 3. Spectrum of hard X-rays, obtained from PF, at W_0 = 50 kJ and filling gas – Ar at P_0 = 0.4 Torr.

and slow drift of the temperature of the details inside it.

4. The case of the calorimeter is made of soft steel to protect it from external slowly changing magnetic fields. These fields can generate voltage on the wires of the thermocouples comparable with useful signals.

The thermodynamic properties of the targets are indicated in Table 1, and common design of the calorimeter is shown in Fig. 2. The specially designed two-cascade 8-channel amplifier is included between the calorimeter and an oscilloscope. Low noise bipolar operational amplifiers are used in the first cascades of this amplifier. The differentiating R-C circuit of time constant 3 s, connected between the first and second cascades of the amplifier, reduces to acceptable magnitude the output voltage drift of the amplifier. The upper bound of the frequency passband of the amplifier (~1 Hz) is determined by the integrating R-C circuits on an input and between cascades of the amplifier. The noise level of the amplifier is lower than 100 nV. The eight thermocouples connected in series and the level of noise of the amplifier allows to measure the target temperature changing less than 10^{-3} K and X-ray fluxes less than 10^{-4} J/cm^2.

Fig. 3 shows the usual X-ray spectrum from the PF facility at a 50 kJ stored energy and 0.4 Torr Ar filling gas. This spectrum is similar to one obtained in the work [1].

Summary

The multichannel calorimeter, based on the splitted target, absorbing X-rays, can measure X-ray fluxes from 10^{-4} J/cm^2 with certain spectral resolution. It is shown that in the range 10–200 keV the full spectral range can be divided into eight subranges.

Acknowledgments The author is grateful to Professor N.V. Filippov, without whom this work could not started and to A.K. Vinogradova without whom this work would not be fulfilled.

References

1. Filippov NV, Filippova TI, Karakin MA et al. (1996) Filippov type plasma focus as intense source of hard X-rays. IEEE Trans Plasma Science 24;4:1215–1223