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DESENVOLVIMENTO DE UMA SONDA REMOTA PARA USO EM ESPECTROSCOPIA PORTÁTIL

Francisco Antônio Brandão Junior[1,2], Arno Heeren de Oliveira[1] and Antonella Lombardi Costa[1]
[1] Departamento de Engenharia Nuclear, Universidade Federal de Minas Gerais (DEN/UFMG)
Av. Antônio Carlos, 6627 – Escola de Engenharia – Pampulha , CEP 31270-901 Belo Horizonte, MG, Brasil
[2] Centro Federal de Educação Tecnológica de Minas Gerais
Av. Amazonas 5253, Nova Suiça, CEP 30421-169 Belo Horizonte, MG, Brasil

RESUMO

A sonda remota proposta neste trabalho consiste principalmente no uso de um cabo de fibra ótica de alta definição devidamente acoplado a um detector do tipo iodeto de sódio dopado com tálio - NaI(Tl) – por um lado, e a uma válvula fotomultiplicadora pela outra extremidade. Esta montagem inova o sistema tradicional utilizado em que o detector é diretamente acoplado à fotomultiplicadora limitando seu alcance. Esta sonda portátil simplifica grandemente o sistema de detecção e poderia trazer novas soluções para esse tipo de procedimento, uma vez que poderia chegar a áreas de aplicação que o dispositivo tradicional não pode alcançar devido à sua falta de mobilidade e às suas dimensões externas. As fibras têm uma grande faixa de passagem, pequena atenuação de sinal, imunidade à interferência eletromagnética e menor custo em relação aos cabos elétricos. Lentes focalizadoras e dispositivos para o acoplamento foram especialmente fabricados para a concepção do sistema. São apresentados neste trabalho os primeiros testes de detecção com este sistema. Como será demonstrado, os resultados iniciais encorajam a continuidade do desenvolvimento do sistema proposto.

1. Introduction

The technique of photon induced energy dispersive X-ray fluorescence (EDXRF) is very valuable for several studies as those related to works of art and ancient documents mainly due to its nondestructive characteristic, as can be verified, for example, in [1, 2]. Moreover it is relatively simple and few expensive. In this way, an essential characteristic of the EDXRF apparatus is the portability to possibility its application *in situ*.

2. Experimental Device - the Remote Probe

The production of optical fibers cables made possible the development of a range of spectroscopic probes for *in situ* analysis [3]. The idea of this work was to construct an innovative device for coupling detector and photomultiplier through an optic fiber cable type step index multimode; one side of the device is joined to a NaI(Tl) detector and the other side is connected to a photomultiplier valve as it is shown in the **Fig. 1**. The internal cylinder space is conical and dark painted and each one has an adjustable system of converging lenses (**Fig. 2**) that focuses the beam from the detector (fluorescence) on the optical fiber, on which it travels through by total reflection, reaching the other extremity of the probe and being focalized and distributed in the surface of the photomultiplier. It simplifies the detection system. **Fig. 3** shows the probe ready together with the associated electronics to perform X-ray fluorescence spectrometry. The photomultiplier detector can be easily coupled to the probe making possible fast permutation of detectors with different sensitive volumes if it is necessary according with the work to be performed. The optical fiber cable used is the model GX-4-2000 (STORZE STYLE) Multimode step index. It has high definition, diameter of 4 mm, length of 2 meters and minimum wavelength of 380 nm.

Figure 1. Prototype developed - photomultiplier coupled with a NaI(Tl) detector using a remote probe of optical fiber.

Figure 2. Converging lenses, with 60.0 cm (left) and 32.0 cm (right) of diameter.

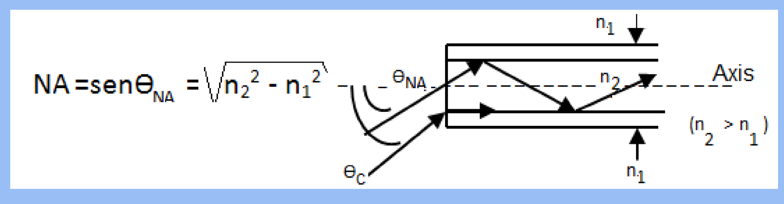
Figure 3. The probe ready to detection.

3. Results and Conclusions

A) Adjustment of the Light Gather Cone of the Fiber with the Light Gather Cone of the Lens

The adjustment was performed with the experimental dispositive of the **Fig. 4** according with the fiber Numeric Aperture (NA) and Critical Angle, where n_1 is the refractive index of the cladding and n_2 is the refractive index of the core.

$$NA = sen\Theta_{NA} = \sqrt{n_2^2 - n_1^2}$$



B) Experimental System

The photos of the luminescence (obtained with a digital camera) after crossing the optic fiber can be seen in the **Fig. 5** in according with the cases from 1 up to 8 presented in the **Table 1**. As it can be verified, there is a small difference in the areas of the images due to the size of the detectors and variations in brightness according with the X-ray energies. The detector characteristics are:
D-I : NaI(Tl) Detector; Optical window area: 5.15 cm^2, Sensitivity Volume: 23.27 cm^3
D-II: NaI(Tl) Detector, Optical window area: 9.68 cm^2, Sensitivity Volume: 225.16 cm^3

C) First Spectrometry Results Using the Remote Probe

Verification tests of the remote probe were performed at the Laboratory of Nuclear Instrumentation of DEN-UFMG. The equipment for gamma spectrometry is the conventional system for NaI(Tl) detectors and consists of a high voltage source, preamplifier, multi-channel amplifier, counter, timer and computer monitor GENIUS 2000 software. Spectrometry to assess the remote probe was performed under several conditions to obtain results to verify the system performance. Firstly, it was verified the background signal (**Figs 6 and 7**). After, it was obtained a spectrum resulting from the Am^{241} source (**Fig. 8**) and, finally, a X-ray spectrum (**Fig. 9**). These first results are in according with the expected behavior and encourage the continuity of the tests with this innovative device.

Fig 4. Device for measuring of the fiber acceptance angle using a laser light and a compact size digital lux meter (MLM-1011) Minipa, measuring range from 1 up to 100000 lux.

Table 1. Luminescence Experimental Cases.

Case	Detector	V (kV)	I (mA)	Time (s)	D1* (cm)	D2** (cm)
1	D-I	120	100	0,7	40	In Contact
2	D-I	100	100	0,7	40	In Contact
3	D-I	80	100	0,7	40	In Contact
4	D-I	60	100	0,7	40	In Contact
5	D-II	120	100	0,7	40	In Contact
6	D-II	100	100	0,7	40	In Contact
7	D-II	80	100	0,7	40	In Contact
8	D-II	70	100	0,7	40	In Contact

***Distance between focus and detector centre**
****Distance between movie camera and difusor lens**

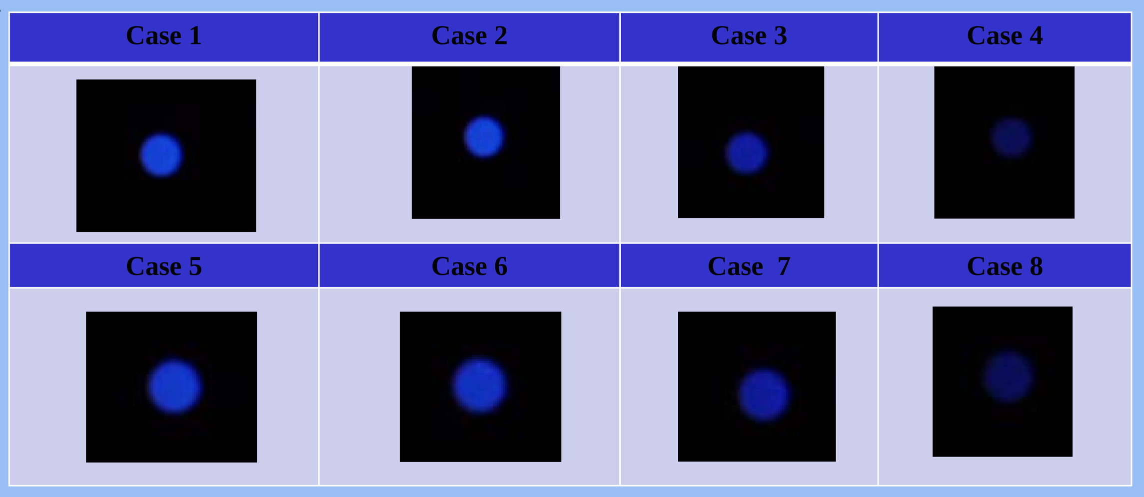


Fig. 5. Luminescence signal obtained after crossing the optic fiber.

Figure 6. Results of the BG in the laboratory (Off Expand and VFS 1M). The upper figure shows a peak in the channel 99 (1,976 counts) and the lower figure is a peak in the channel 757 (602,335 counts). The VFS picture shows the complete background spectrum. Channels marked by limiters were observed: 60 (50 counts) and 120 (783 counts).

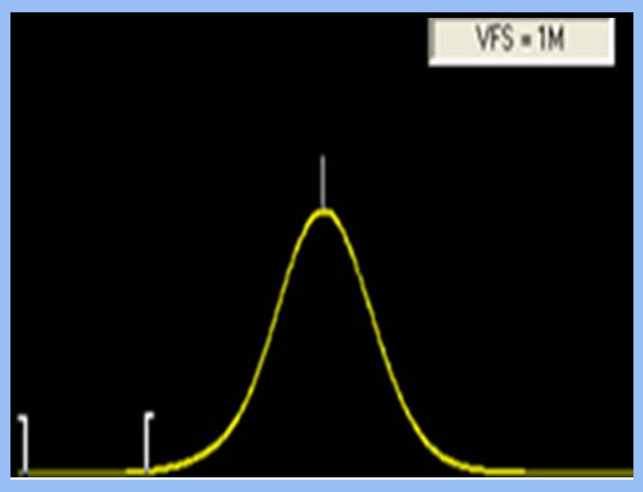


Figure 7. Result of the BG in the laboratory room. It will be compared with the standard source of americium the laboratory under the same conditions spectrum.

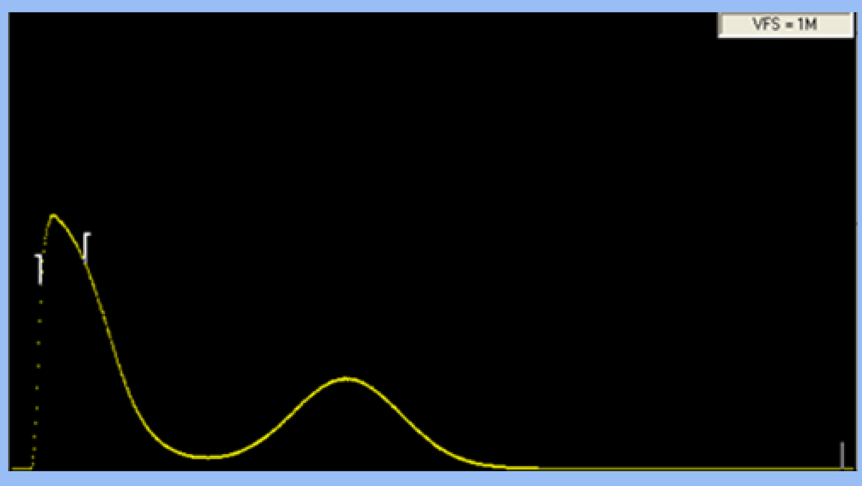


Figure 8. Spectrum resulting from the Am^{241} source, obtained under the same conditions as the BG. In this case, the first peak occurred on channel 102 (585,355 counts) compared to that of the channel 99 BG, presented 296 times larger, therefore confirming the presence of the Am^{241} source of 60 KeV. The second peak is the same as appears in this case and BG shifted to the channel 814 (209,537 counts).

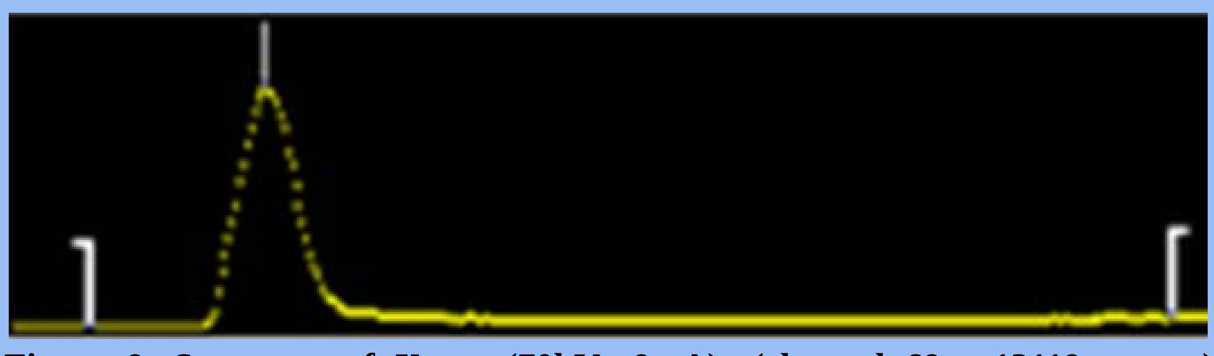


Figure 9. Spectrum of X-ray (70kVp-9mA): (channel 69 - 13119 counts). According with the Am^{241} source (60 KeV), the main X-ray peak indicates a energy of about 44.0 keV. It is in according with the expected energy. Therefore, the system using the innovative probe seems work well.

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