BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
10-03B (2022) 01-07

Development of an additional filtration system by 3D printing for the implementation of new X-ray beam qualities used in diagnostic radiology

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ABSTRACT

The Calibration Laboratory (LCI) of the Nuclear and Energy Research Institute (IPEN-CNEN) offers calibration services for radiation measurements instruments used in radiation protection, diagnostic radiology and radiotherapy. LCI produces radiation qualities and irradiation conditions which are in accordance with the national and international standard requirements. In order to establish the recommended radiation qualities for diagnostic radiology, X-ray beams generated in laboratory are modified for the irradiation conditions found in equipment routinely used in healthcare services. In this work, a new additional filtration system was developed to be adapted to the existing filter system at LCI. The new filter support can be coupled to the PTW Bench Control installed at the LCI X-ray system. Using a FDM 3D printer, a support model and a set of drawers were developed for the placement of additional filters. The models were also developed to fit each specific drawer of each filter to be used in the laboratory routine, coupled to the specific sensors that fit the spaces of the support part. Additionally, a microcontroller based on Arduino, micro switches, low- and high-level programming, allow checking of drawer status and integration of information with the laboratory control system. The system allows the recognition of the filter inserted in the drawer from sensors attached to the support. Tests were carried out to verify the usability of the system in the routine, adding Ag (silver) and Cu (copper) filters, for the characterization of attenuated radiation beams of interest in diagnostic radiology.

Keywords: **Additional Filtration, Diagnostic Radiology, 3D Printing, Prototyping, Calibration.**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2022.1992
Submitted: 2022-01-31
Accepted: 2022-18-05

1. INTRODUCTION

The Calibration Laboratory (LCI) of the Nuclear and Energy Research Institute (IPEN/CNEN) offers calibration services for radiation measurements instruments used in radiation protection, diagnostic radiology and radiotherapy.

LCI produces radiation qualities and irradiation conditions which are in accordance with the national and international standard requirements [1, 2]. In order to establish the recommended radiation qualities for diagnostic radiology, X-ray beams generated in laboratory are modified for the irradiation conditions found in equipment routinely used in healthcare services [3, 4].

2. MATERIALS AND METHODS

In this work, a new additional filtration system was developed to be adapted to the existing filter system at LCI. The new filter support can be coupled to the *PTW® Filter Wheel*, installed at the LCI X-ray system (fig.1).

Figure 1: *Pantak X-ray irradiator system and PTW filter wheel at LCI/IPEN*.

The models were also developed to fit each specific drawer of each filter to be used in the laboratory routine, coupled to the specific sensors that fit the spaces of the support part. Fig. 2 shows the model developed at the open source software OpenSCAD [5].

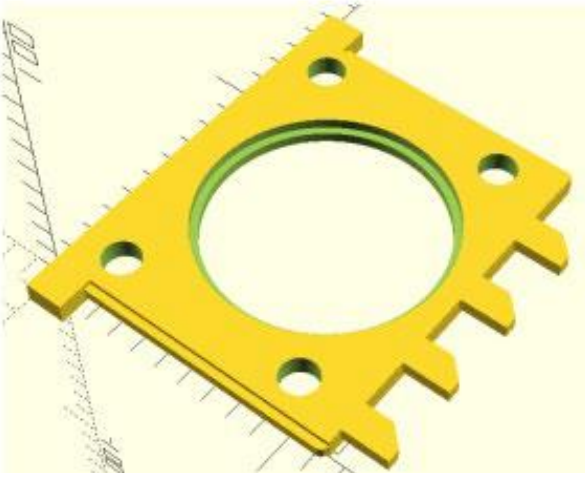
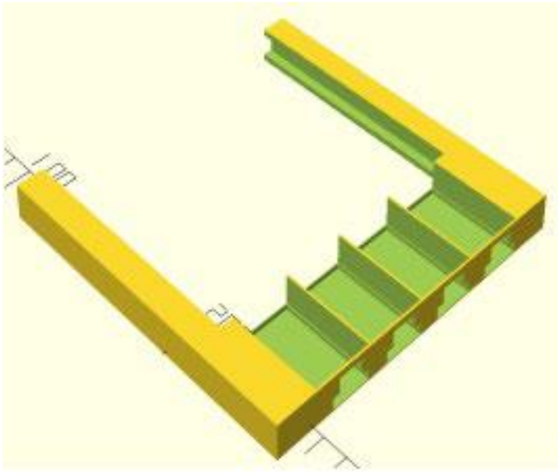
(a)  (b) 

Figure 2: *Prototype developed at OpenSCAD open source software of (a) support and (b) drawer.*

Using a Fused Deposition Modeling (FDM) 3D printer, a support model and a set of drawers were printed [6, 7] for the placement of additional filters (fig.3).

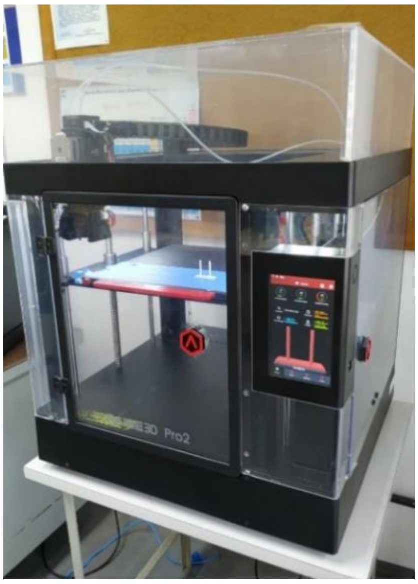
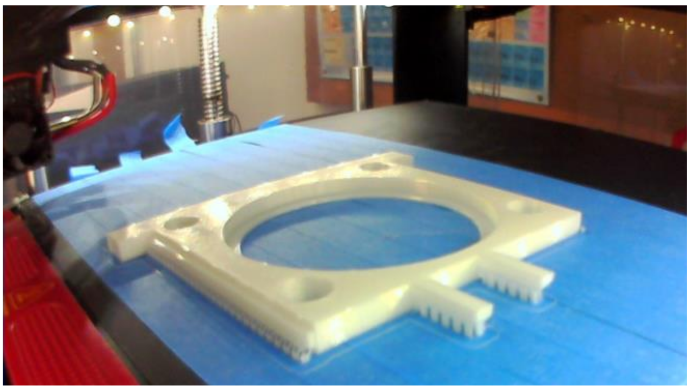
(a)  (b) 

Figure 3: *(a) image of the FDM 3D printer (Raise3D PRO [8]), (b) and a drawer being printed.*

In order to be able to give versatility to the current calibration system, the prototypes of the drawer and of the support was printing using polylactic acid (PLA) filament, with settings adjusted for printing without skirt (contour involving the piece).

The main printing parameters are shown in Table 1. The purpose for that was reducing the problems of precision in the first layer. It was also used for infill density of 25%, with retraction and infill speed in 70 mm/s, so that it had a sufficient infill adjustment to avoid deformation and sufficient print time for drawer to maintain stamina when fitting with the support. This option is suitable for PLA printing, including prior calibration on the X, Y and Z axes of the table, improving printing accuracy.

Table 1: Principal parameters settled in the 3D printer.

Parameters	Values
Infill density	10 to 100% (depending on what part printed)
Layer heigh	0.150 mm
Shell overlap	50%
Extrusion width	0.40 mm
Retraction speed	60 mm/s
Infill speed	70 mm/s
Table temperature	60 ºC
Extrusion temperature	205 ºC

Each drawer has a distinct set of pins that trigger 4 sensors fixed to the support. This system allows the identification of 2^4 states of the system, each state is associated with a drawer. The sensors, based on micro switches, are connected to an Arduino microcontroller that communicates with the control room computer, continuously informing which filter is in the holder. The IDE of Arduino microcontroller communicates with the system, detecting by the sign of the sensor selected, transmitting to the *PTW BenchControl* routine of the LCI X-ray system, which drawer is located, by the sequence implemented in the code.

3. RESULTS AND DISCUSSION

Fig. 4 shows the assembly for support with the four sensors attached in the spaces and the contact of the drawer (in this example with Al filter).

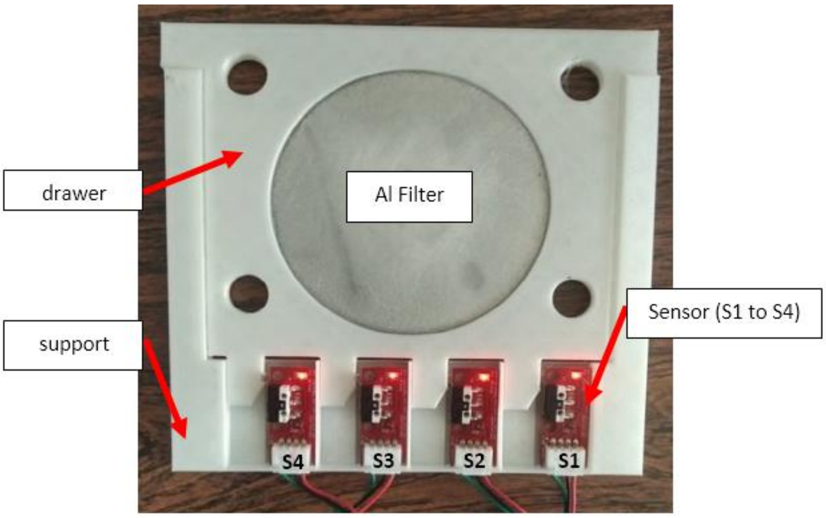


Figure 4: I*mage of drawer and support with the sensors at the bottom of support.*

Fig. 5 shows the schematic situation for recognition and register of the filter.

Figure 5: *the whole schematic situation for recognition of the filter attached in the drawer.*

In this situation, the Arduino® software recognizes the specific filter attached at the draw, by the sensor in high state. The combination of sensors generates a specific data at the COM serial. This serial communicates with the Processing® software that generates both .csv file (DataLogger.csv) and a .txt file.

The .txt file will be used for filter recognition, implemented at the routine for PTW Bench Control®, at the PC Control Room. The PTW® Bench Control®, finally, indicates what filter is located at the PTW® Filter Wheel.

Tests were carried out to verify the usability of the system in the routine, adding Ag (silver) and Cu (copper) filters, for the characterization of attenuated radiation beams of interest in diagnostic radiology [9, 10].

4. CONCLUSION

In view of the activities carried out, this work is in the final phase for the adequacy for the LCI X-ray system, for usability of the new system of recognition of additional filter in the routine. Thus, with the operation of the system, new qualities of radiation can be implanted.

ACKNOWLEDGMENT

The authors would like to thank the support provided by the Instituto de Pesquisas Energéticas e Nucleares and the Comissão Nacional de Energia Nuclear, CNEN – Brazil (grant process SEI no. 01342.004839/2020- 61), for the Master Degree scholarship granted to José Neres de Almeida Jr.

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