LASER-GUIDED PRECISION: TRANSFORMING X-RAY RADIOLOGY PRACTICE FOROPTIMAL COLLIMATOR ALIGNMENT AND ENHANCED PATIENT SAFETY

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Abstract: In X-ray radiology, conventional practice of using light or lamps to indicate the field size during the collimation process has notable limitations. The reliance on a dark room for accurate representation of the effective field of exposure restricts the practical application of collimation. Troublingly, instances of radiographers blatantly disregarding collimators and opting for full-field exposure to expedite workflow have been observed. This paper presents a groundbreaking solution that leverages laser technology for precise collimator alignment, fundamentally transforming behavioral practices within the field and effectively minimizing the risks associated with harmful X-ray effects. This innovative approach holds tremendous promise for revolutionizing X-ray radiology practice, ensuring unparalleled collimator alignment accuracy, and bolstering patient safety.

Keywords: X-ray radiology, Collimation process, Laser technology, Behavioral practices, patient safety, Revolutionary solution

Introduction:

A radiology collimator serves as a device placed at the exit window of an X-ray generator. Its purpose is to limit the size of the X-ray field to the specific area of interest. By doing so, it effectively eliminates unnecessary radiation and optimizes the diagnostic results while minimizing exposure to X-ray energy. Typically, collimators consist of two sets of parallel blades that can move independently, enabling the adjustment of rectangular field sizes according to the anatomical region under examination. Collimators play a vital role in different kinds of X-ray equipment, such as stationary, mobile, and portable devices. Compliance with regulatory standards mandates the use of collimators to reduce unnecessary exposure to X-rays. Field adjustments could be performed manually or through motorized mechanisms as shown in figure1.

Collimation holds significant importance in X-ray radiology as it is a crucial procedure employed to restrict the dimensions of the X-ray field to the precise region of focus. However, visualizing the size of the field exposed to X-ray energy is not possible due to the invisible nature of X-rays. To overcome this challenge, collimators are equipped with a light field that provides a visual reference on the body of a patient. The light field is an important tool that provides a visible representation of the configured field of view, indicating its actual size, location, and position. Through the integration of a light field, collimators facilitate precise and accurate collimation, effectively reducing unnecessary exposure to X-rays. The incorporation of a light field is a common practice in contemporary X-ray radiology collimators.

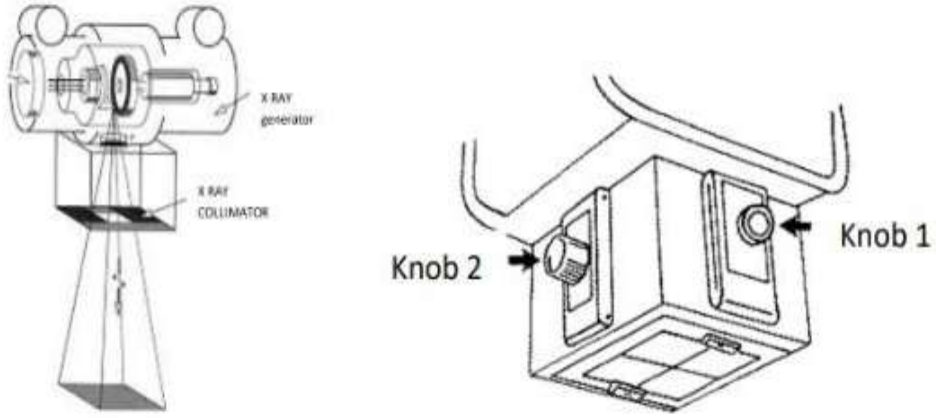

Figure 1 (a) Figure 1 (b)

Figure 1 (a) Working of Collimator (b) Knobs for Manual Operation

During the collimation process, when the user makes adjustments to the collimator, a precise field of view is projected onto the patient's body through a light field. This interactive process enables a clear visualization of the actual collimated X-ray field, allowing radiologists to optimize the field size and obtain high-quality diagnostic images while minimizing the patient's exposure to X-ray radiation.

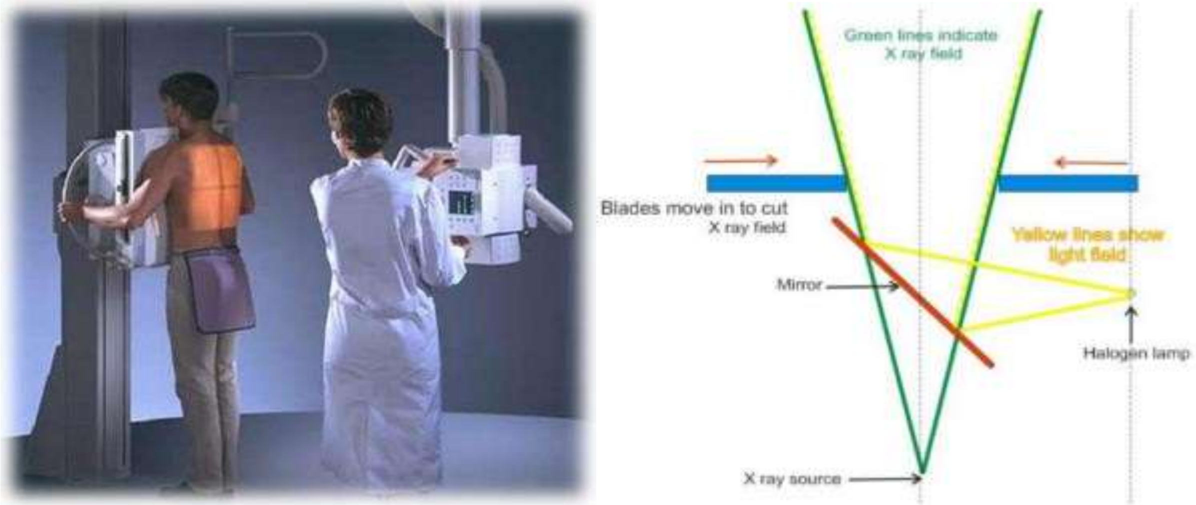

Figure 2 (a) Illuminating Field Size on Patient (b) Light Field Mechanism

Illuminating Field Size on Patient: Visualizing the exposed field in X-ray radiology is challenging. Collimators integrate a light field on the patient's body, providing a direct size reference.

Light Field Mechanism: Collimators employ optical elements and light sources to project a visible light pattern. LED or laser diodes are commonly used.

To ensure the accuracy of the X-ray field, a 45-degree mirror is strategically positioned to coordinate the high-intensity Halogen lamp with the X-ray field. Through meticulous alignment of these components, as the collimator's rectangular blades move, both the X-ray and light fields undergo synchronized modifications, ensuring that the light field faithfully reflects the X-ray field during exposure.

In radiology rooms, the implementation of this innovative approach has demonstrated its effectiveness by ensuring optimal visibility of the light field. However, challenges arise in environments such as ICUs and general wards, where abundant lighting may interfere with the visibility of the field. As a result, there is a potential risk of users inadvertently leaving the collimator blades fully open when capturing X-rays. To address this issue, a thorough study has been conducted to examine the complexities and limitations of current collimation methods. The subsequent section provides a concise summary of the insightful findings from this comprehensive research.

Inferences from Field Study

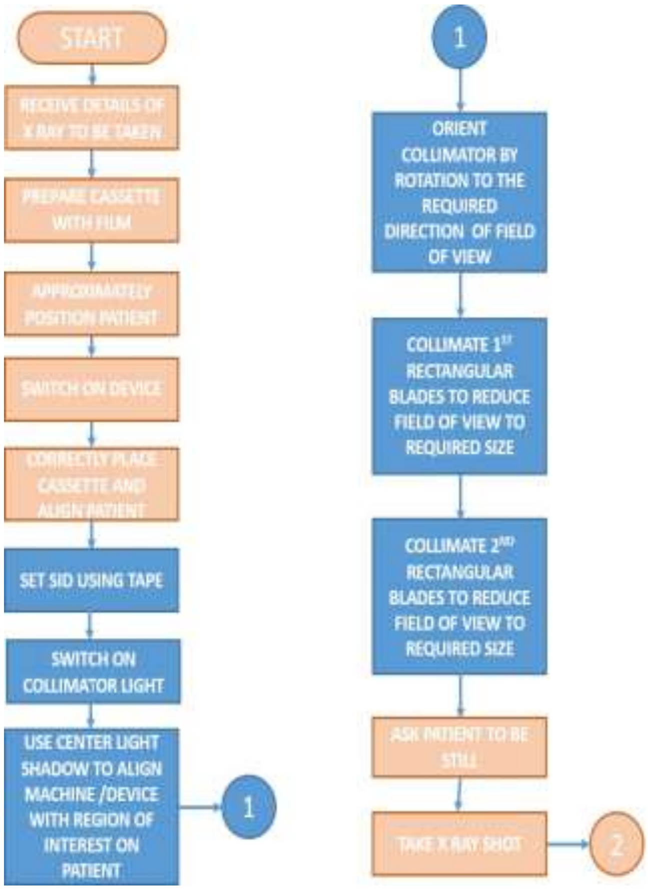

Figure 3: X-Ray Imaging Workflow: Patient Prep, Positioning, Device Configuration, Image Capture

Extensive field studies have uncovered several important discoveries, highlighting a significant issue concerning the visibility of the field size. Traditionally, collimators have utilized high-wattage halogen lamps or LED lights to indicate the field size. Nevertheless, this method poses challenges due to the excessive generation of heat and high energy consumption.

Figure 3 provides a comprehensive analysis of the workflow involved in X-ray imaging, offering detailed insights into each step of the process. The collimator-related procedures are highlighted in blue, while the remaining steps encompass the broader workflow.

The usage of high-energy lamps in battery-powered and portable systems poses challenges, leading to inefficient power consumption. This issue becomes particularly evident when considering the collimation field light, which necessitates a substantial allocation of energy storage. Addressing this concern is paramount in order to optimize power utilization and enhance the overall efficiency of battery-based and portable options. By exploring alternative solutions to make the field size visible without relying on high-wattage halogen lamps or LED lights, it is possible to mitigate power- related drawbacks and improve the performance of these systems. Finding innovative approaches to address this issue will contribute to more efficient and sustainable X-ray imaging practices.

Time Constraints in Field Setting: Due to the high heat generated by lamps and their susceptibilityto burn out, they must be switched off within a limited time frame of 10 to 15 seconds to prevent damage. This leaves radiographers with a narrow window to accomplish alignment tasks.

Issues of Lamp Failures and Misuse: In cases where the lamp malfunctions during a procedure, some hospitals opt to continue without a collimator. The blades are fully opened, resulting in unnecessary radiation exposure.

Limitations in Well-Lit Environments: The current method is primarily suitable for fixed room radiography, where the environment can be darkened to ensure clear visibility of the field size indicated by the lamp. However, mobile and portable radiology devices used in various settings face limitations as not all environments can be darkened.

Addressing Risk in Radiography: The third edition of IEC 60601-1 places responsibility on manufacturers to mitigate risks associated with device use. By reducing the drawbacks of the current collimation system and minimizing the risk of unnecessary exposure, we can establish a precedent for safer radiography practices. The findings from comprehensive field studies emphasize the urgentneed for more effective collimation methods.

Proposed Solution

Introducing Laser-Based Collimation:

The suggested resolution offers an alternative to conventional lamps by proposing the utilization of lasers with a power output of up to 5mW to accomplish the identical objective as the light collimator. In the existing design of the light collimator, lead or tungsten blades are employed to move in straight lines for cutting the X-ray field. Meanwhile, a simulated light field serves as a representation of the actual size of the X-ray, acting as a reference. However, due to the large field size reaching dimensions of 450 mm x 450 mm at a distance of 1 meter, the light intensity diminishes, leading to inadequate visibility and necessitating a dimly lit room. The innovative approach focuses on highlighting the boundary rather than illuminating the entire area. By using lasers to create clear, sharp light edges indicating the boundary, the energy required for illumination is reduced significantly, around 56 times less compared to illuminating the entire area. This enables the use of lower wattage lamps and directs the energy specifically to the boundary, resulting in substantially reduced energy requirements.

Moreover, the design proposes the use of lasers, which offer improved visibility at lower energy levels. By employing four 5 mW lasers to indicate each boundary, a much clearer and easily visible field is achieved. Consequently, the power load of the field indication system is reduced from typical systems using a 12 W LED or 50 W halogen lamp (may vary) to a laser-based system consuming only 0.01 W.

To execute this solution, adjustments are made to the blade mechanism. The blades are now moved in a concentric manner towards the focal point of the X-ray field, as depicted in the diagram below. Consequently, any line laser positioned to emit perpendicular to both the center of rotation of the blade and the focal point of the X-ray consistently portrays the accurate field size. Moreover, laser technology is utilized to accomplish the task of creating the center mark necessary for initial positioning.

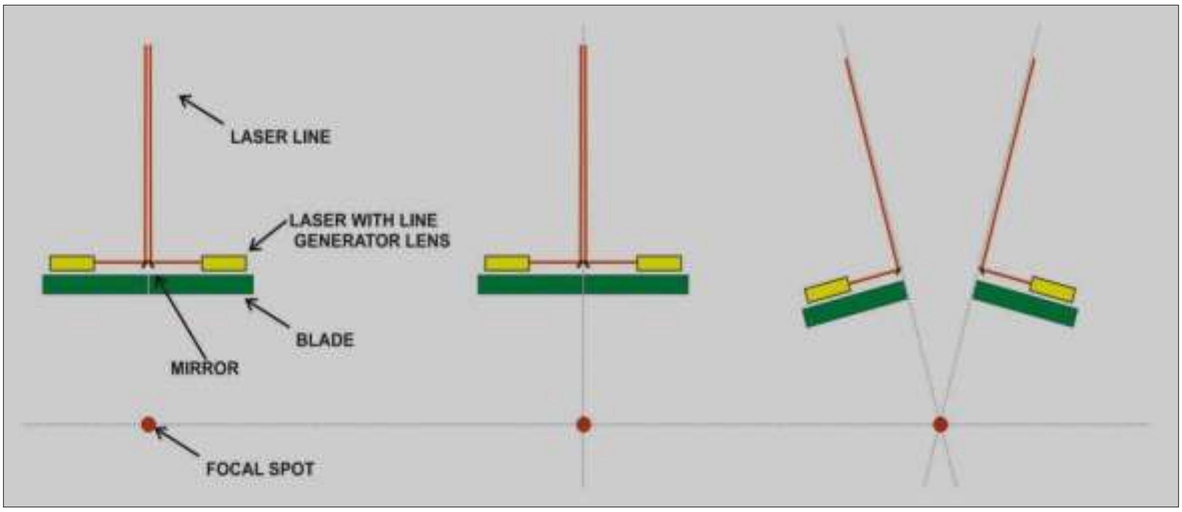

Figure 4 Mechanism of Proposed Solution

By implementing a novel approach, the power requirements for the task previously carried out by 9-12 W LED lamps or 50 W halogen lamps have been drastically reduced. Now, the same task is accomplished using a set of six lasers, each with a capacity of 5mW, resulting in a total power output of 30 mW. This significant reduction in power consumption enhances energy efficiency.

Furthermore, the team has introduced motorized blade motion, eliminating the need for frequent movement of the radiographer between the protected area and the collimator. This advancement enables all control operations to be conveniently executed from the main panel, simplifying the workflow and optimizing user convenience.

Design Detailing of the New Idea

The figures presented illustrate the successful implementation of the proposed solution. Figure 5 showcases different views of the mechanism without its cover.

(a) Presents a side view (b) displays a front view, and (c) exhibits a top view. In addition, (d) illustrates a top view of the mechanism including the positioning laser external.

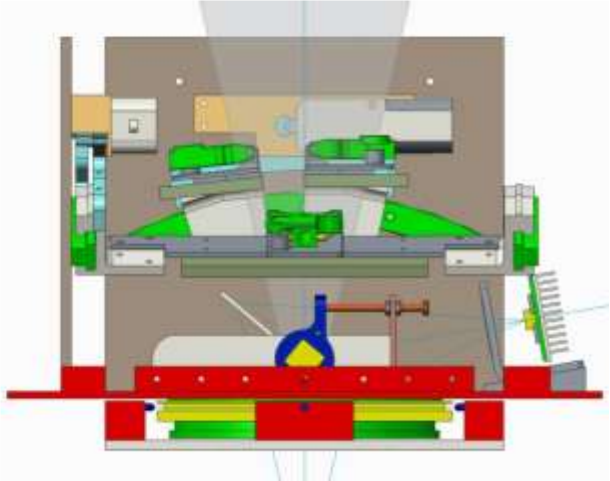

Figure 5 (a)

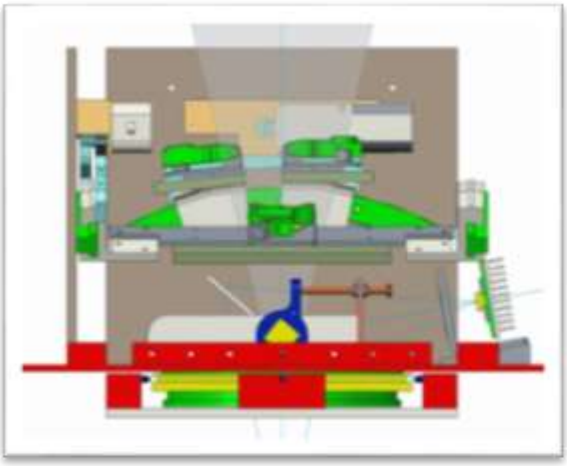

Figure 5 (b)

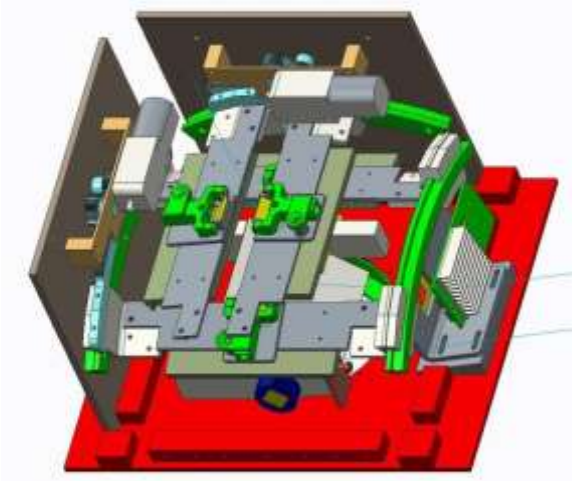

Figure 5 (c)

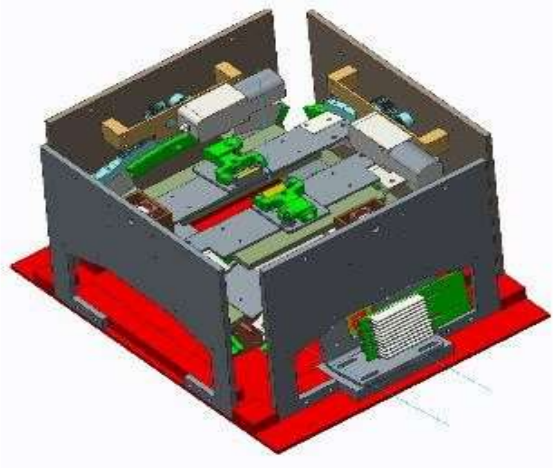

Figure 5 (d)

It is important to highlight that in the initial designs, the decision was made to retain the light and mirror system, despite its lack of necessity. This choice was motivated by the need to provide a real-time comparison between the new proposed solution and the existing approach. By including the old light system, we can clearly demonstrate the performance difference and effectiveness of the new design.

Furthermore, the decision to incorporate the light system in the current version of the new design is also influenced by X-ray regulatory standards. These standards currently mandate the presence of a light-based system to differentiate the exposed area. This requirement exists due to the absence of a more efficient alternative at the time. In order to gain market acceptance and comply with regulatory guidelines, we must initially incorporate the traditional light system while simultaneously showcasing the superior performance and efficiency of our laser-based solution. Once our innovative approach becomes widely adopted, regulatory changes can be pursued and enforced to reflect the advancements in the field.

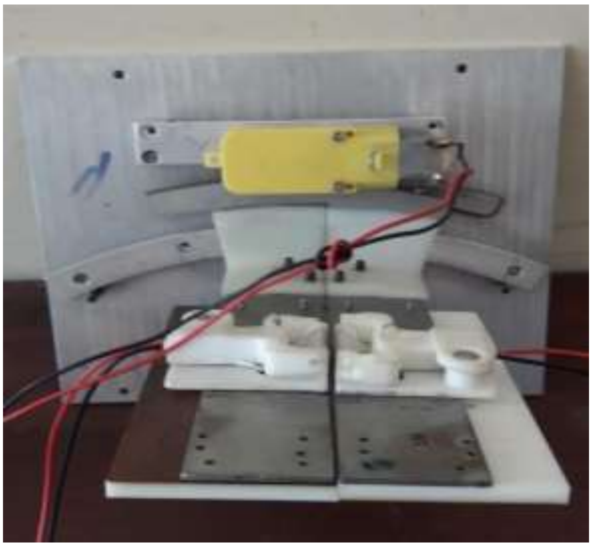

Figure 6 (a)

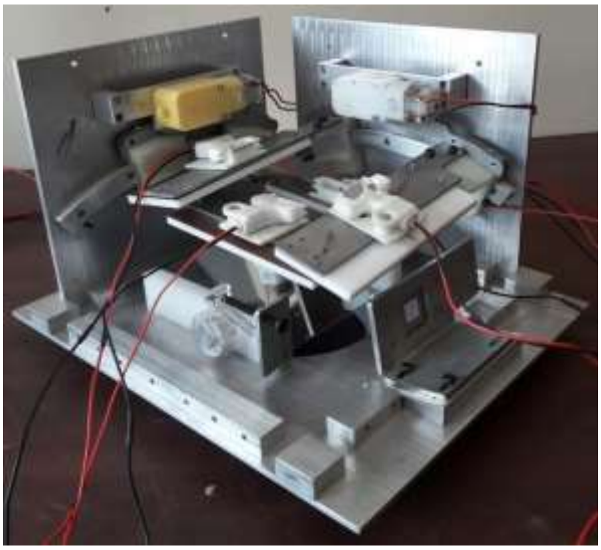

Figure 6 (b)

Figure 6 (c) Figure 6 (d)

Figure 6: (a) Lead Blade Assembly (b)Ortho View of Assembly (c) Top View of Assembly (d) Laser Light Emission

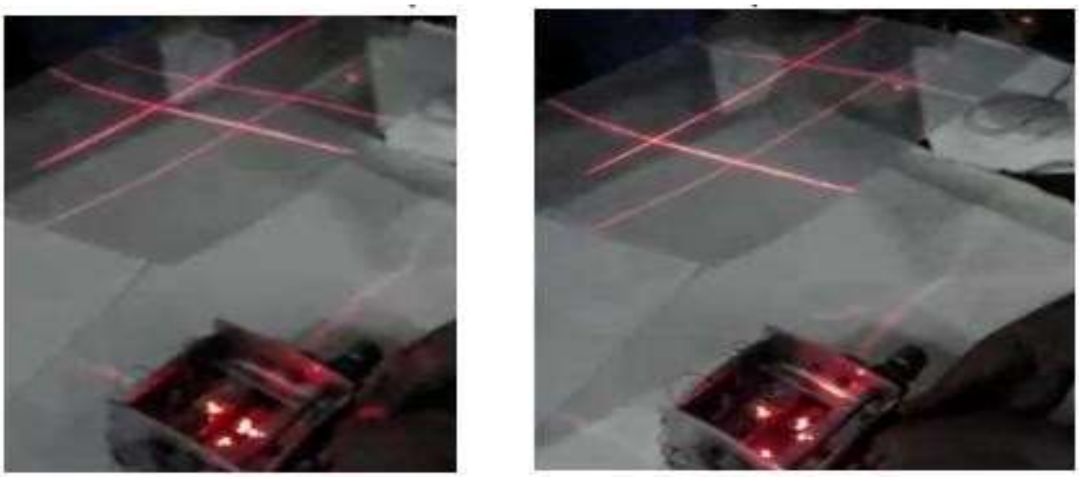

Figure 7: (a) and (b) Image shows the field size as represented by laser lines instead of light on a darkened transparency

Figure 8: (a) and (b) Product packaged in Rapid prototype covers for the client demonstration using manual controls.

Conclusion

The safety of radiologists and patients is of utmost importance in the field of Radiology. It is essential to carefully consider the potential risks of X-ray exposure and the benefits of obtaining accurate diagnostic images. With the advent of portable technologies, X-ray applications have expanded beyond fixed rooms to various field environments. This innovation offers a significant and effective solution that enhances the usability and efficiency of collimators in diverse settings. By incorporating motorization, the collimator can be easily controlled from a convenient rear panel, simplifying the process. With the tightening of regulations in India, there is a growing alignment of medical standards with international guidelines. It is crucial to comply with safety measures and provide safer products. This endeavor represents a significant milestone in advancing collimation systems for the evolving needs of Radiology applications.

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