



Global Voice
for the
Radiation
Processing
Industry

Communicate.
Educate.
Advocate.

16 October 2025

全球辐射行业市场 技术与应用情况

Global developments in
the business and technologies
of radiation processing

彭伟，国际辐照协会 中国/亚洲代表

Wei PENG, China/Asia Representative of iia

A decorative graphic on the left side of the slide features a grid of white dots on a light blue background. The grid lines are slightly curved, creating a perspective effect that draws the eye towards the right. The dots are arranged in a pattern that resembles a mesh or a lattice structure.

引言 *Introduction*

- 辐射加工的发展 *The Evolution of Radiation Processing*
- 辐射加工技术的现状与最新进展 *The Status & Recent Developments in Radiation Processing Technologies*
 - 伽马 *Gamma*
 - 电子束和X射线 *Electron-beam & X-Ray*
 - 剂量测量系统及剂量计 *Dosimetry and dosimeters*
 - 计算及软件 *Computing & Software*
- 辐射加工的未来 *The future of Radiation Processing*

辐射加工的发展 *The Evolution of Radiation Processing*

基于十九世纪末期和二十世纪初期的基础研究

Building on foundational research of the late 19th / early 20th Century

1950s / 1960s 商业应用的发展 *Development of commercial applications*

1970s / 1980s 产业化发展 *Development on an industry*

1990s – 2020 整合与国际扩张 *Consolidation and international expansion*

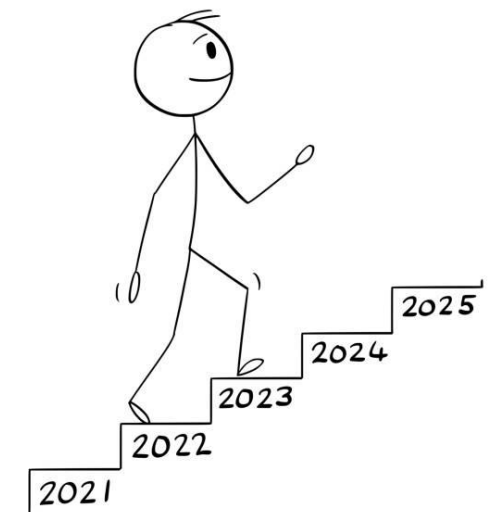
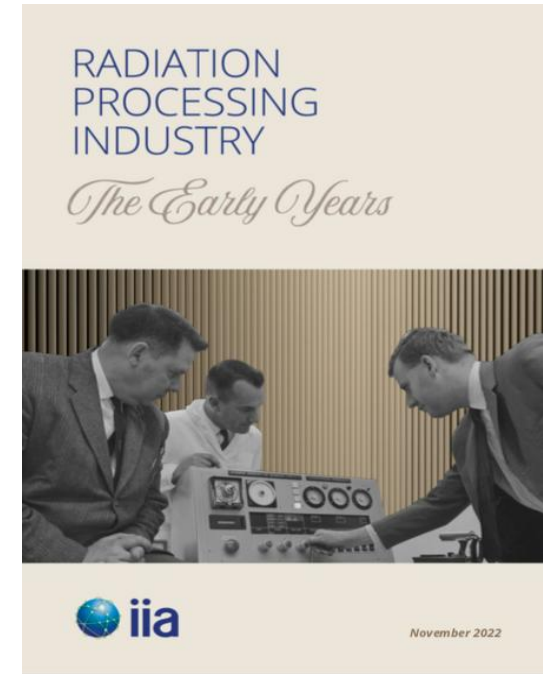
2021 -

优化时代? *The age of optimisation?*

环保时代? *The age of the environment?*

加速器时代? *The age of the accelerator?*

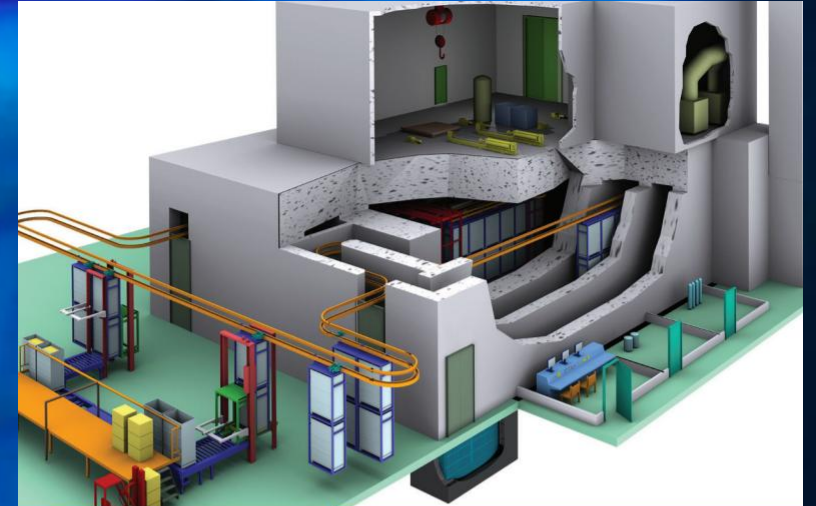
未来 *The future* 前景光明! *Bright!*



伽马 GAMMA

现状与最新进展

*Status & Recent
Developments*



factsheet

Gamma Irradiation Technology using Cobalt-60

Gamma irradiation technology is used in a wide variety of industrial applications and uses Cobalt-60 as the source of ionizing radiation.

伽马-现状与进展 (1)

GAMMA – Status & Developments (1)

- 全球300座装置 300 facilities worldwide
- 装源4亿居里 400MCi installed
- 80%用于灭菌 80% for sterilisation
- 每年处理250亿件 25 billion items per year
- 成熟产业 Mature industry
- 历史上占主导地位 Historically dominant

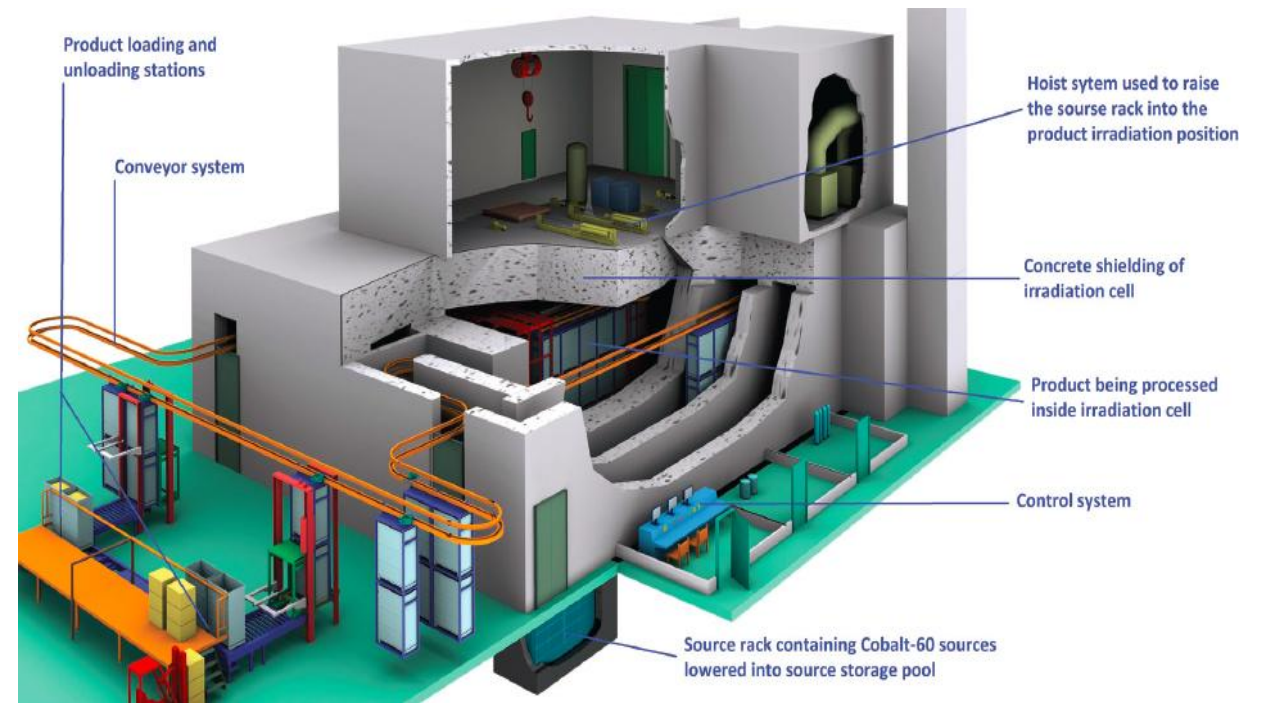
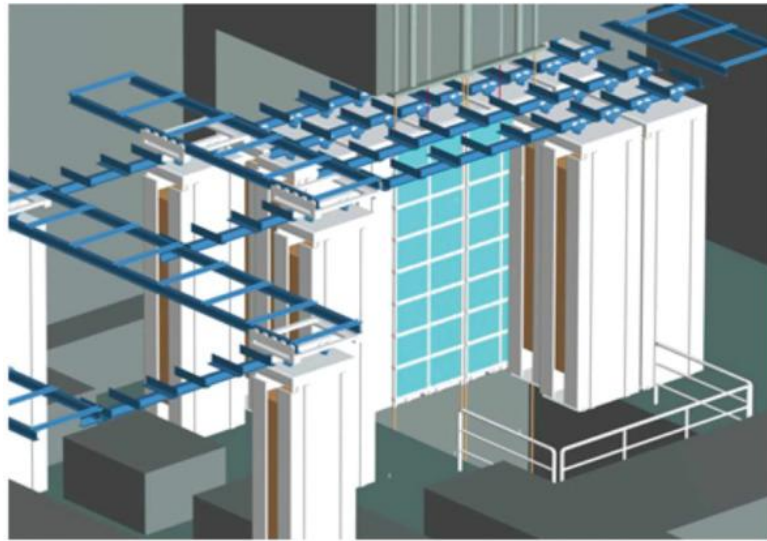


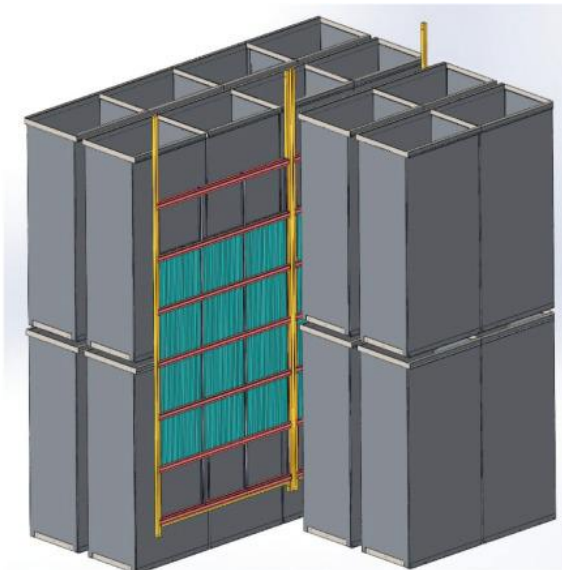
Image courtesy of SQHL Radiation Engineering Technology Co., Ltd.

伽马-现状与进展 (2)

GAMMA – Status & Developments (2)



Source overlap
2 + 2 pass
Single level
Hanging carriers



Product overlap
2 + 2 pass
Two level
Large totes

➤ 产品输送模式 Product transport configurations

纸箱、拖箱、吊架、托盘

Boxes, totes, carriers, pallets

通道 Passes: 1+1, 2+2, 4+4

层数 Levels: 1, 2, 4, 5

➤ 计算机/过程控制 Computer/process control

产品调度 Product scheduling

产品追踪 Product tracking

安全和安保系统 Safety and security systems

伽马-现状与进展 (3)

GAMMA – Status & Developments (3)

钴-60的供应vs需求 Cobalt-60 Supply vs Demand

供应：仅阿根廷、加拿大、中国、印度与俄罗斯生产；反应堆关闭、改造与新型号；基础设施、厂房、运营能力、法规体系... Supply: Only Manufactured in Argentina, Canada, China, India and Russia; Reactor closures, refurbishment and new types; Infrastructure, facilities, operational capabilities, regulation...

需求：无菌医疗器械的需求驱动；人口增长与老龄化、医疗资源普及、新型器械涌现 Demand: Driven by need for sterile medical devices; Growing and ageing population, access to healthcare, new devices

- 2014	过剩 Surplus	2014年俄罗斯与阿根廷供应中断 2014 Russia and Argentina supply disruption
2014-2017	满足需求 Meet demand	靠库存满足需求 Demand met from stock
2018-2024	紧张 Tightness	加拿大反应堆翻新，俄罗斯供应减少，需求激增 Canadian reactor refurbishment programmes Russian supply reduced, exceptional increase in demand
2025-2035	满足需求 Meet demand	翻新及新建反应堆投运，需求趋缓 Refurbished and new reactors come on line, moderation in demand
2035-	潜在过剩 Potential surplus	更多反应堆即将生产钴-60 Additional reactors to come on-line for Co-60

伽马-现状与进展 (4)

GAMMA – Status & Developments (4)

➤ 拒绝运输 Denial of Shipment

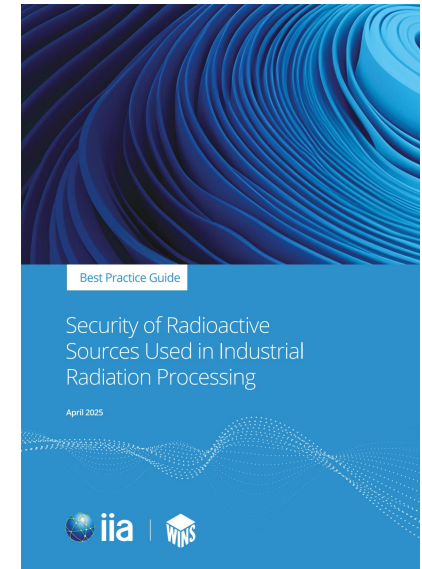
“.....在运输过程中的任何环节， 尽管完全符合所有适用法规要求， 仍拒绝承运或接收放射性货物.....”国际原子能机构拒绝运输工作组

➤ ‘...refusal to carry or accept a shipment of radioactive material at any point during transport though it conforms to all applicable regulatory requirements...’ IAEA Denial of shipment Working Group

➤ 安保 Security

“对涉及或针对核材料、其他放射性材料、相关设施或相关活动的犯罪行为或故意未经授权行为， 进行预防、探测和应对。 国际原子能机构核安全与核安保术语， 2022

➤ ‘*The prevention and detection of, and response to, criminal or intentional unauthorized acts involving or directed at nuclear material, other radioactive material, associated facilities or associated activities.*’ IAEA Nuclear Safety and Security Glossary, 2022



电子束和X射线

E-BEAM & X-RAY

现状与最新进展

Status & Recent Developments

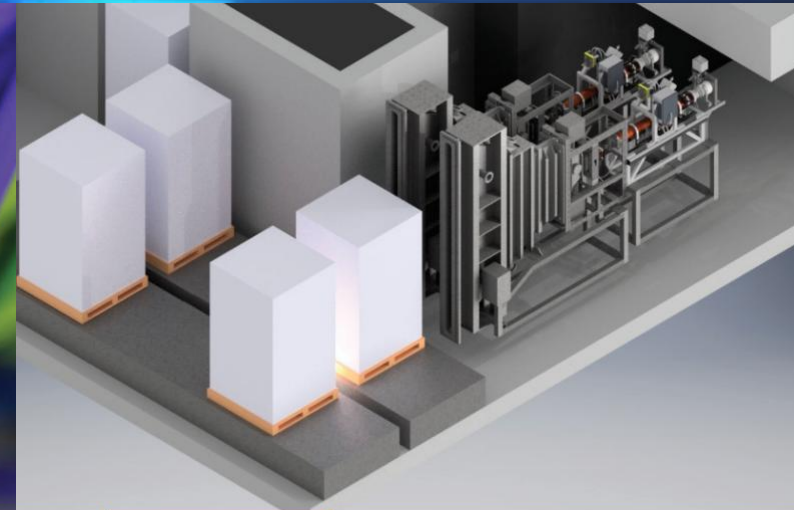


factsheet

Electron Beam Technology

Electron beams (EB) are one of three types of ionizing radiation used in industry and research, the other two being gamma rays and X rays.

Initially designed for scientific research, the first electron accelerators used for industrial purpose were installed in the 1950s. Electron beam accelerators are now used in diverse industries chiefly to enhance the physical and chemical properties of materials. Cross-linking of polymers used for wires, cables and heat-shrinkable products is a major application. Accelerated electrons are also used to inactivate microorganisms or to reduce the quantity of pathogens or toxic by-products in polluted waters.



factsheet

X-rays

Within a year of their discovery by Roentgen in 1895, X-rays were applied to medical diagnosis and therapy. It took another century before they started to be used for industrial processing.

X-rays refers to electromagnetic radiation (no rest mass, no charge) of high energies travelling at the speed of light and ionizing matter essentially via indirect ionization. Like gamma radiation, X-rays are high-energy photons, but gamma rays are emitted at defined energies during the radioactive decay of elements such as cobalt-60. X-rays are emitted as a spectrum of energies in a continuous way by the interaction of accelerated electrons with atoms' electrons and nuclei.



EB/X-现状与进展 (1)

EB/X – Status & Developments (1)

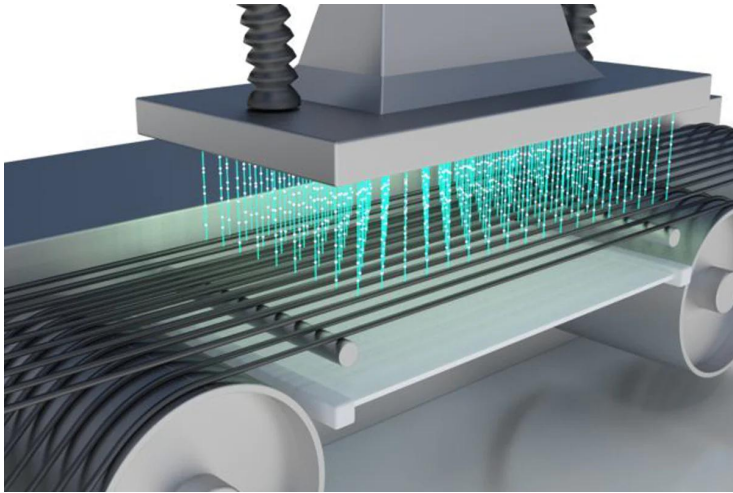
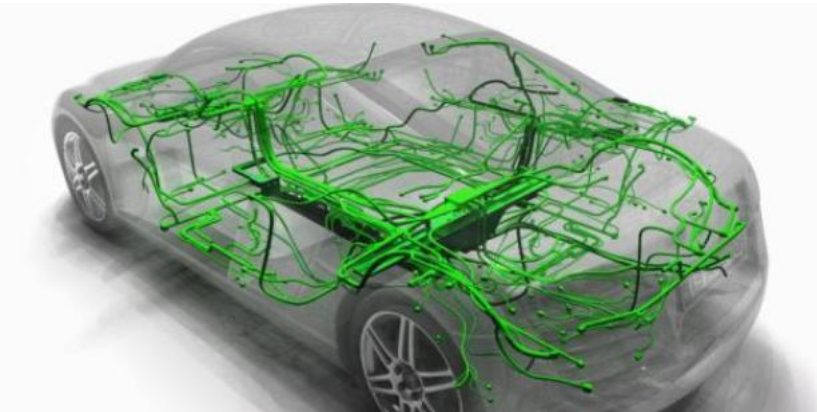


Image courtesy of Tirupati Plastomatics Pvt. Ltd. 'Gemini Cables'



- 自20世纪90年代以来保持良好增长，市场竞争激烈 Shown good growth since 1990's, competitive market
(供应商遍布欧洲、美国、加拿大、中国、日本、俄罗斯、印度 suppliers in Europe, US, Canada, China, Japan, Russia, India)
- 全球约3500座装置 ~3500 facilities worldwide
- 高能-中能-低能 High – Medium – Low energy
- 主要用途为交联，尤其是电线电缆行业 Primary application is crosslinking, particularly in wire and cable industry
- 通过技术创新提升可靠性、效率与灵活性 Technical innovations to improve reliability, efficiency and flexibility
- X射线应用日益普及 Greater adoption of X-ray

EB/X-现状与进展 (2)

EB/X – Status & Developments (2)



➤ 脉冲束流 Pulsed beam

降低平均功耗，使机器在低功率下效率更高。采用脉冲束的现役设备，可比老款连续束设备节省约一半电力 Reduces average power consumption so machines efficiency is improved at low power. Current machines using pulsed beam can save up to half the power of older machines using continuous beam

示例：IBA TT200 10MeV 设备在40kW下，效率可由17%提升至27%。 Example: Efficiency of IBA TT200 10MeV machine can be improved from 17% to 27% at 40kW.

冷却需求减少，设计可更简化、紧凑，成本也随之降低。 Reduced requirement for cooling can result in simplified, compact designs at reduced cost.

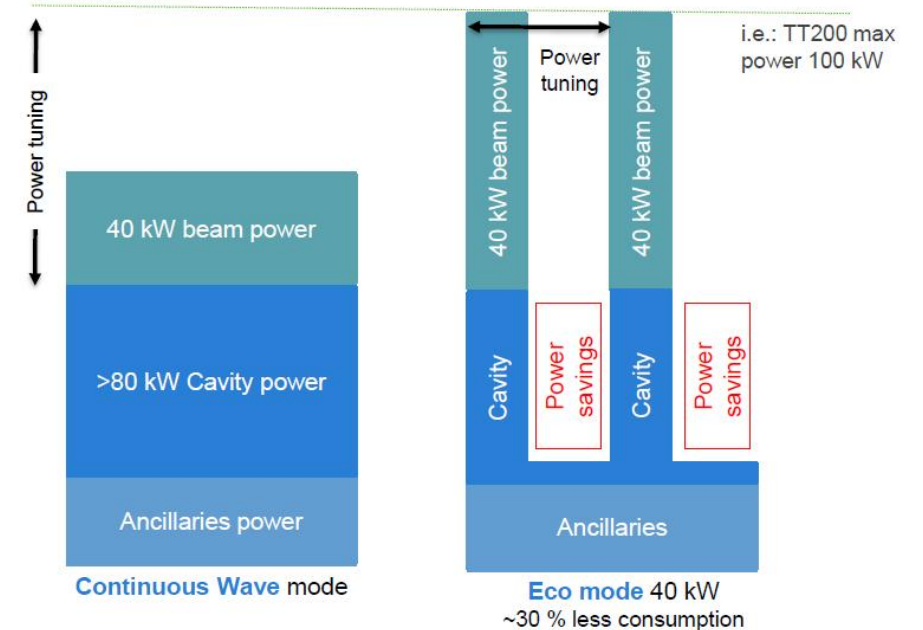


Illustration courtesy of IBA Industrial. Refers to IBA TT200 Rhodotron

EB/X-现状与进展 (3)

EB/X – Status & Developments (3)



➤ 多束流与可变能量 Multiple beams & variable energies

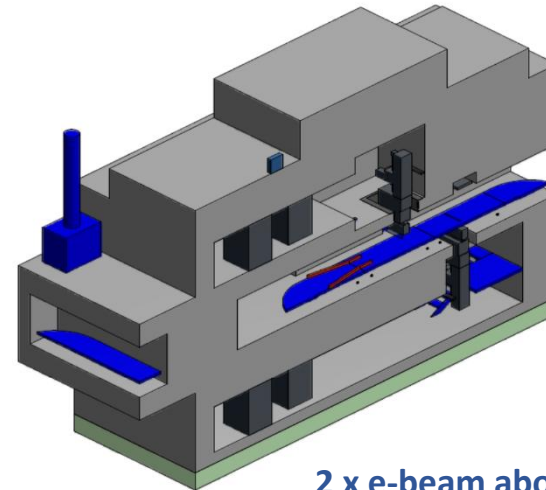
单台或多台加速器输出2或3束流；因客户需处理多种产品而开发。 2 or 3 beams from one or more accelerators.
Developed as a result of demand from customers that need to process wide range of products



E-beam and x-ray from same beam

- by moving x-ray target in or out
- maximum flexibility to treat wide product range

Illustration courtesy of IBA Industrial



2 x e-beam above and below conveyor

- high throughput, low DUR, no product rotation
- flexibility and back-up

Illustration courtesy of MEVEX Corporation

EB/X-现状与进展 (4)

EB/X – Status & Developments (4)



- 固态电源-向告别功率电子管迈进 Solid State Power – a move away from power tubes

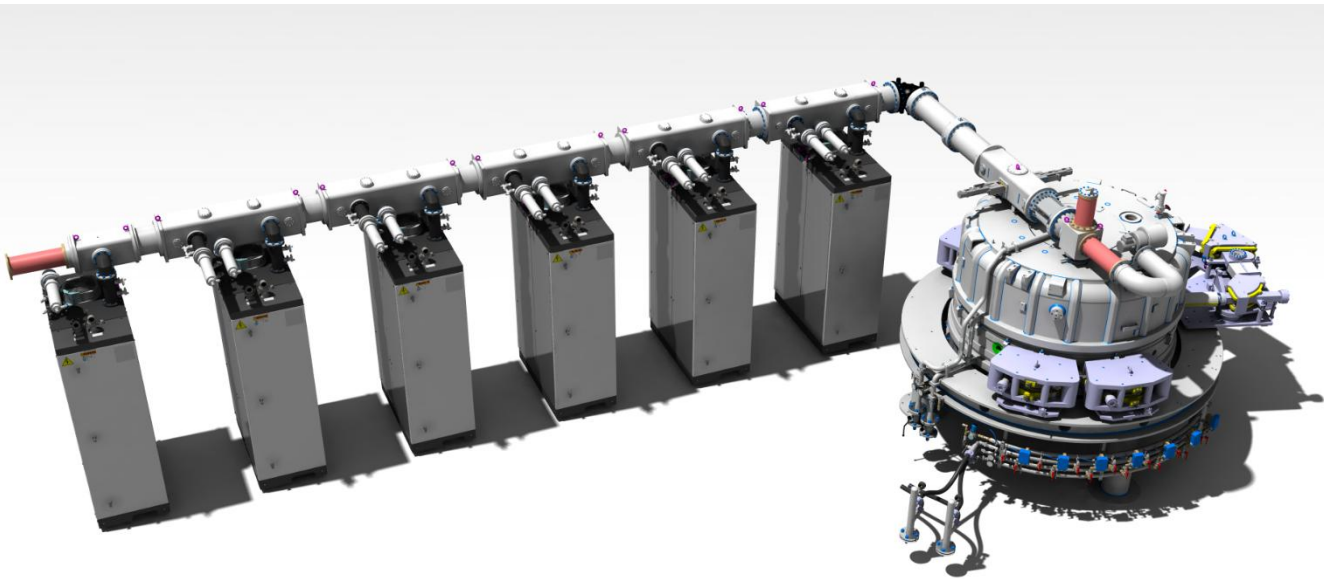


Image courtesy of IBA Industrial

效率更高 Superior efficiency

低压安全 Safe at low voltage

即插即用，无需调谐

Plug & Play with no tuning required

全冗余设计 Fully redundant

全模块化 Fully modular from 20kW to 1MW


可升级 Retrofittable

面向未来 Future proof (vs tube obsolescence)

占用较大物理空间 Requires a lot of physical space

EB/X-现状与进展 (5)

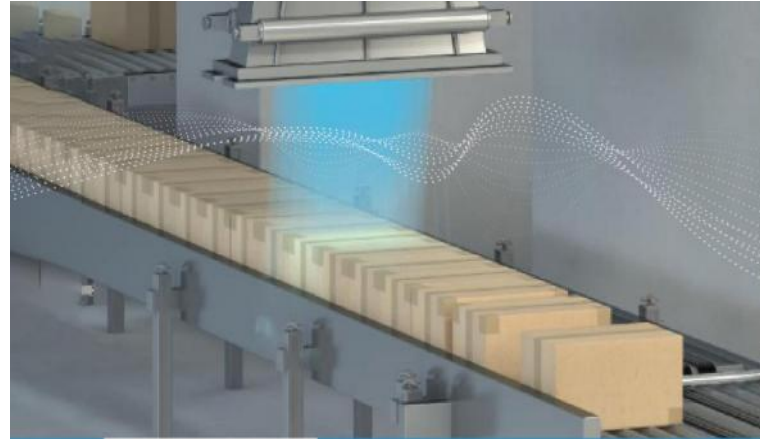

EB/X – Status & Developments (5)



buyer's guide

Roadmap to an Electron Beam or X-ray Center for Industrial Applications

Eb/X Working Group





buyer's guide

Accelerators for Sterilization of Medical Devices

A Guide for Prospective Buyers

EB-X Working Group | May 2021



white paper

A Comparison of Gamma, E-beam, X-ray and Ethylene Oxide Technologies for the Industrial Sterilization of Medical Devices and Healthcare Products

AUGUST 31, 2017

剂量测量系统及剂量计

DOSIMETRY & DOSIMETERS

现状与最新进展

Status & Recent Developments

剂量测量系统与剂量计 现状与发展 (1)

Dosimetry & Dosimeters – Status & Developments (1)

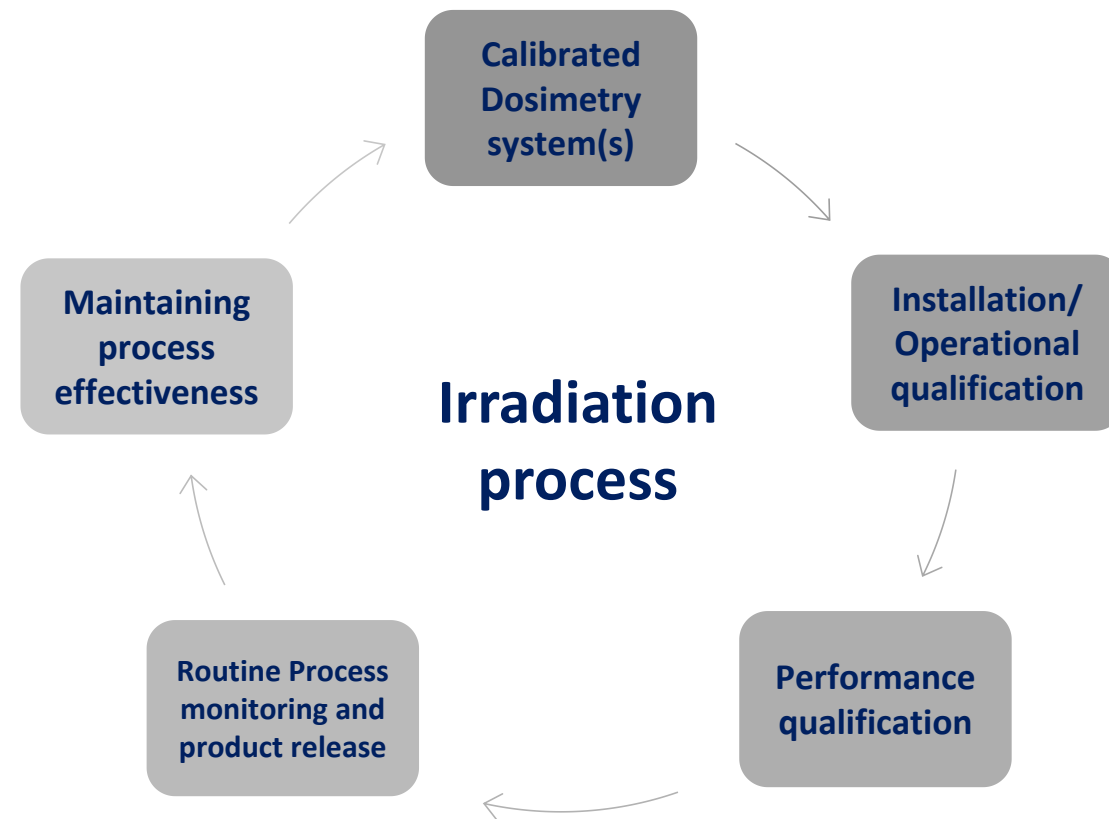
➤ 工艺确认 (IQ/OQ) 与产品确认 (PQ) 均需使用经过校准的剂量测定系统。 Calibrated dosimetry systems needed for qualification of the process (IQ/OQ) and product (PQ)

➤ 根据这些结果, 可以确立监测剂量接收限 (以及产品剂量接收限) 和辐照工艺参数。 From these results one can establish monitoring dose acceptance limits (and product dose acceptance limits) and irradiation parameters

→ 剂量测定是辐照工艺的核心参数。 Dosimetry is the key parameter to master/control



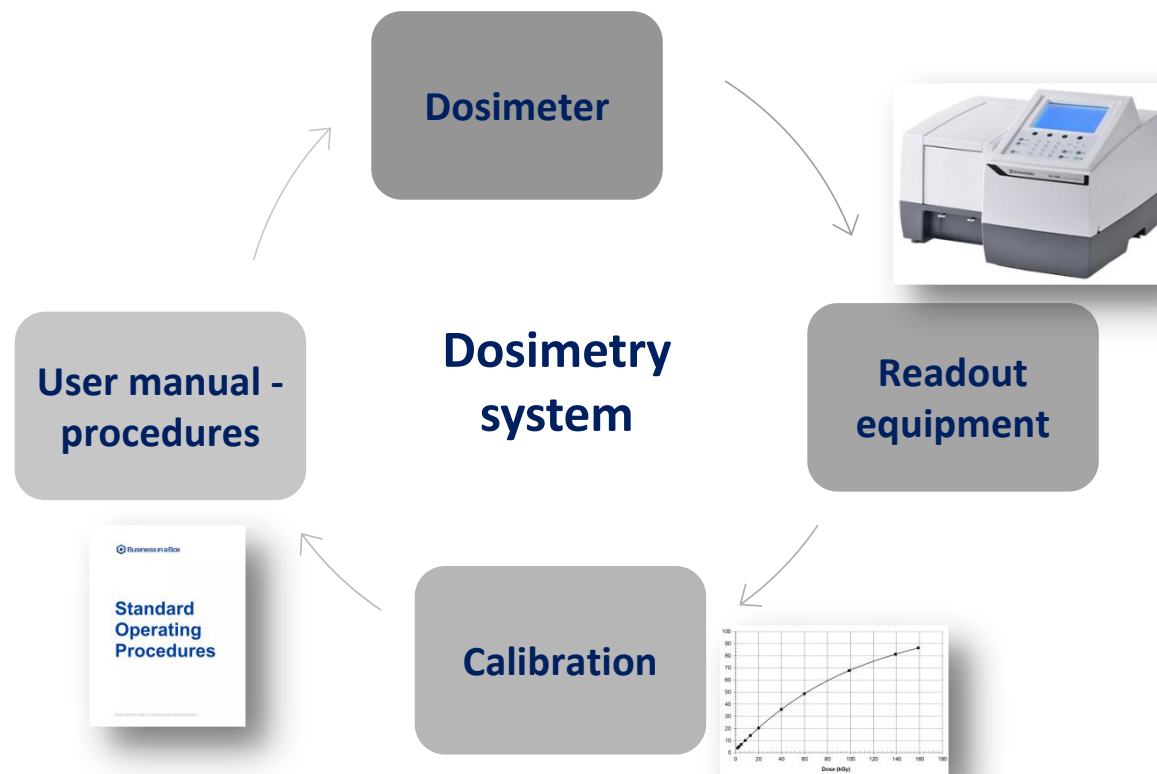
伽马、电子束和X射线剂量测定及剂量计使用良好规范 Good practice for dosimetry and dosimeters of Gamma, EB and X-ray



剂量测量系统与剂量计 现状与发展 (2)

Dosimetry & Dosimeters - Status & Developments (2)

- 剂量计 Dosimeters
 - 量热法 Calorimetric
 - 物理法 Physical
 - 化学法 Chemical
- 读出设备 Readout equipment
- 剂量测量软件 Dosimetry software
- 剂量校准 Dosimetry Calibration



剂量测量系统与剂量计 现状与发展 (3)

Dosimetry & Dosimeters – Status & Developments (3)

剂量测量和剂量计的主要供应商

Main suppliers of Dosimetry and dosimeters

- 艾里尔-法国 Aerial-France
- 远西科技-美国 Far West Technology-USA
- Gex-美国 Gex-USA
- 哈维尔-英国 Harwell Dosimeters-UK
- Riso-丹麦 Riso- Denmark
- 富士胶片-日本 Fuji Film-Japan

剂量测量和剂量计的国际标准

International standards of Dosimetry and dosimeters

Selection	52628
Calibration	51261
Uncertainties	51707
Influence quantities	52701
Use of individual systems	51026 Fricke, 51205 Ceric-Cerous, 51275 Radiochromic Film, 51276 Polymethylmethacrylate (PMMA), 51310 Radiochromic Optical Waveguide, 51401 Dichromate, 51538 Ethanol-Chlorobenzene, 51607 Alanine-EPR, 51631 Calometric, 51650 Cellulose Triacetate (CTA), 51956 Thermoluminescence (TLD)

计算和软件

*COMPUTING
& SOFTWARE*

现状与最新发展

*Status & Recent
Developments*

计算与软件-现状与进展 (1)

Computing & Software

- Status & Developments (1)

➤ 操作便捷 Ease of Operation

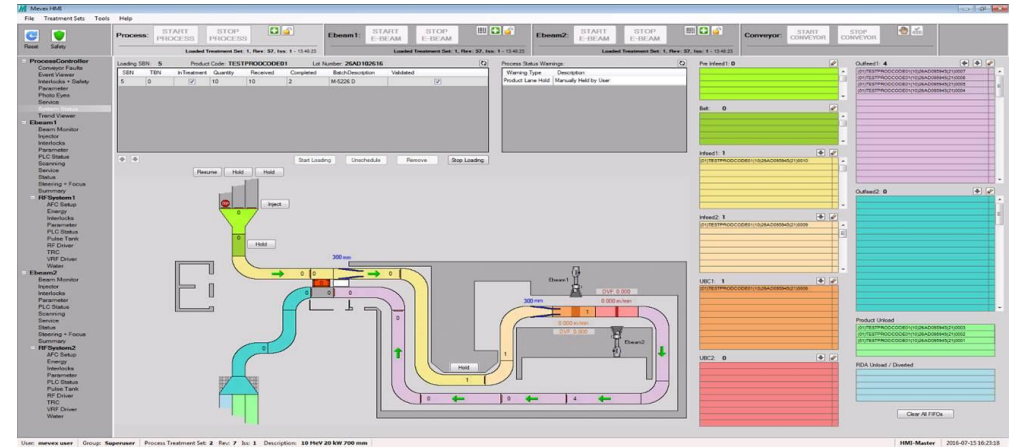
产品加工的调度与追踪 Scheduling and tracking of product processing

安全与安保系统的实时监控 Monitoring of safety and security systems

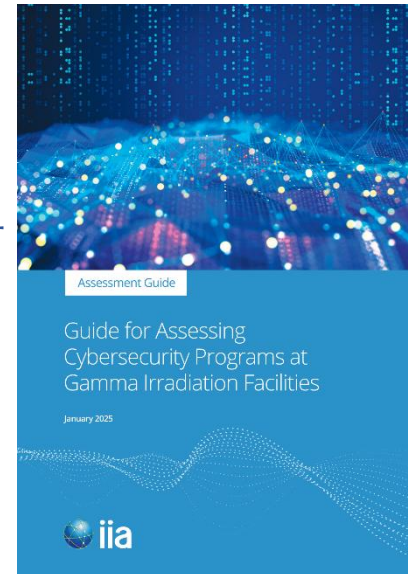
故障诊断与维护需求提示 Troubleshooting and highlighting maintenance requirements

远程访问——IBA已有35个站点接入云端，实时监测3000个信号
Remote access – IBA has 35 sites connected to the cloud with live monitoring of 3000 signals

机器学习刚刚起步 Just seeing introduction of machine learning
网络安全至关重要 Cybersecurity is essential



Images courtesy of MEVEX / STERIS AST

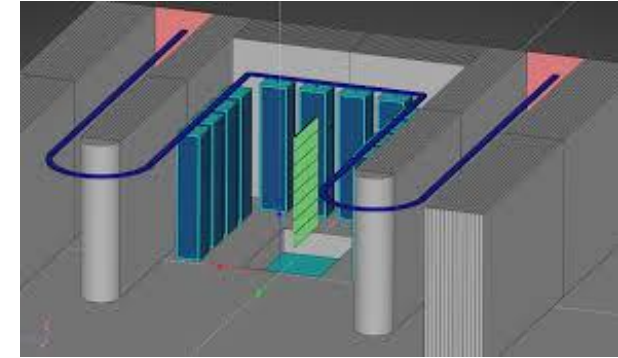
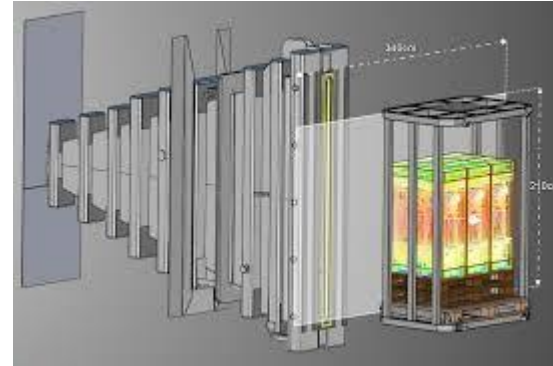


计算与软件-现状与进展 (2)

Computing & Software

- Status & Developments (2)

- 虚拟剂量分布 Virtual dose Mapping
利用蒙特卡罗程序精确预测辐射剂量 Monte Carlo code to provide a precise prediction of radiation dose



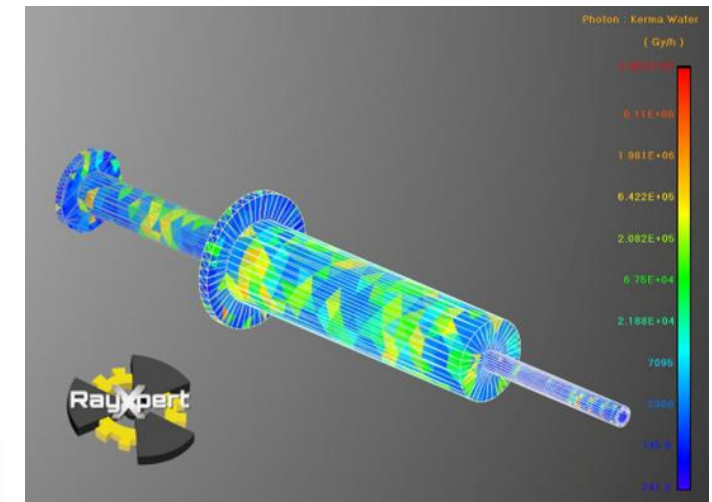
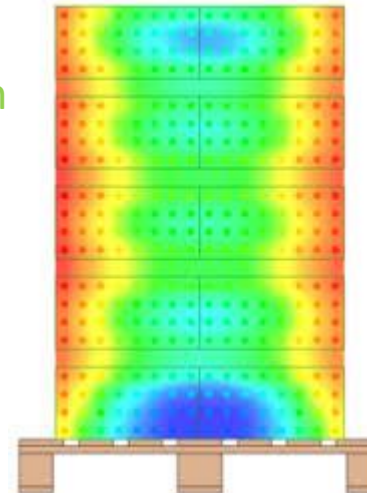
模拟辐照加工并优化工艺以实现最高效率 Simulate radiation processing and modify process for maximum efficiency

Images courtesy of TRAD / RayXpert

适用于产品设计、辐照装置设计、包装方案等 Product design irradiator design, packaging planning etc.

参数放行? Parametric release?

- 三个软件 Three softwares: Dose Insight/RayXpert of TRAD/Pacific Northwest National Laboratory



辐射加工的未来

*THE FUTURE OF
RADIATION
PROCESSING*

前景光明和激动人心

...is bright and exciting



前景光明-伽马

The future is bright - GAMMA

- 灭菌需求驱动下持续增长 Continued growth driven by demand for sterilisation
- 钴-60供应增加 Increased cobalt-60 supply
-翻新及新的反应堆陆续投运 Refurbished and new reactors for Co-60 coming on line
- 仍有增长空间 Room for growth
-新建与现有辐照装置 New and existing irradiators
- 预计低资本支出得以保持 Expect lower capital costs to be maintained
- 对放射性材料使用的管理需求持续存在 Continued need to manage issues around the use of radioactive material



前景光明-电子束/X-射线

The future is bright – EB/X

- 电子束/X射线的应用将持续增加，并从伽马领域抢占市场份额 Adoption of EB/X will increase and take market share from gamma
积压订单释放 / 资本成本降低? Backlog of orders / reduction of capital costs?
 - 面向特定应用开发专用设备 Development of purpose-built machines for specific applications
中等能量 (3-4 MeV)、中等功率、小占地，适用于厂内自用 Medium energy (3 or 4 MeV)
medium power small footprint for in-house applications
高功率 (超导或高功率Rhodotron) 面向环保应用 High power (super conducting or high power Rhodotron) for environmental applications
 - 低能设备应用领域不断扩展 Increased number of applications for low energy
 - 借助束流位置监测仪与X射线通量监测仪，剂量均匀性进一步提升 Improved dose uniformity with use of beam positioning monitors and X-ray flux monitors
-

结论 *Conclusions*

- 辐照让我们安全健康，支撑经济发展，并助力环境保护 Irradiation keeps us safe and healthy, supports our economies and helps to protect the environment
 - 辐射加工是一个充满活力、前景广阔的行业 Radiation processing is a vibrant industry with a strong future
 - 所有辐照方式都仍然不可或缺 All irradiation modalities remain critical
 - 仍大有可为——技术待挖掘，应用待拓展 There's still a lot to be done - technologies to exploit and applications to develop
 - 我们需要具备相应技能的工程师和科学家 We need engineers and scientists with the skills to sustain these technologies
必须鼓励年轻一代投身其中、持续参与 We must encourage the younger generation to stay or become involved
-

发布 *Announcing....*



辐射加工科学与工程

由国际辐照协会（iia）打造的学术与产业社群

SCIENCE & ENGINEERING OF RADIATION PROCESSING

a community hosted by the International Irradiation Association (iia).

本社群汇聚学生、科研人员、工程师及产业界人士，就辐射加工领域的科学发现与商业应用交流观点、探索新进展、强化联系 This group brings together students, researchers, engineers, and industry professionals to exchange ideas, explore new developments, and strengthen connections between science and business in radiation processing

我们将通过定期线上会议保持互动，每次会议设两场简短报告 It will connect through regular online meetings that will feature brief presentations

一个来自学术界，展示早期或在研成果 One from academia, showcasing early-stage or in-progress research

一个来自产业端，提出实际挑战与需求 One from industry, highlighting real-world challenges and needs

报告后设引导式讨论，鼓励对话与观点碰撞 These presentations are followed by moderated discussions that encourage dialogue and exchange of perspectives

我们的目标，是通过畅谈、协作与思想共享，打造一个联通辐射加工科学与产业的活力社群 Our goal is to build a dynamic community that bridges science and industry in radiation processing through conversation, collaboration, and the sharing of ideas.

第二十二届国际辐射加工大会 IMRP International Meeting on Radiation Processing

2027年4月德国 April 2027 in Germany



Science & Engineering of Radiation Processing (SERP)

Public group



Global Voice
for the
Radiation
Processing
Industry

Communicate.
Educate.
Advocate.

THANK YOU

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