EB滅菌ビジネスの世界動向と光子発生技術研究所

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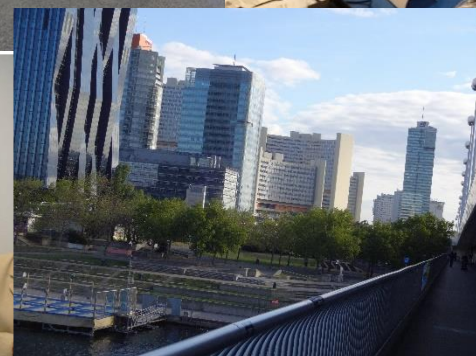
IAEAワークショップ”New Generation of EB Accelerators for Emerging Radiation Processing Applications”出席報告





H. Yamada
JAPAN









IAEA Technical Meeting on

New Generation of EB Accelerators for Emerging Radiation Processing Applications

7-11 September 2015."

IAEA Headquarters Vienna, AUSTRIA

(M0E03 – Meeting Room - Building M)

PROVISIONAL AGENDA

Monday, 7 September 2015

Session I:	**Introductory Session**
9.30 - 10.00	Opening of the meeting by: ➢ Mr Aldo Malavasi, (Deputy Director General, Nuclear Applications) ➢ Ms. M. Venkatesh (Director of Division of Physical and Chemical Sciences) ➢ Mr. Mr Joao Alberto OSSO JUNIOR (Head, Radioisotope Products and Radiation Technology Section) ➢ Mr Sunil Sabharwal(Scientific Secretary) Scope and Objectives of the Technical Meeting Election of the Chairperson and reporter Adoption of the agenda
Session II:	**Participants' Presentations ****
10.30 – 11.30	**Mr. Philippe DETHIER – Belgium** *New 2nd generation Rhodotron*
11.30 – 12.30	**Mr. Wilson CALVO - Brazil** *Mobile Unit with an Electron Beam Accelerator to Treat Industrial Effluents for Reuse Purposes in Brazil*
14.00 – 15.00	**Mr. David BROWN - Canada** *Title to be received*

Tuesday, 8 September 2015

Session II	**Participants' Presentations ****
09.30 – 10.30	**Mr. André WEIDAUER - Germany** *Electron treatment of seed: an environmental friendly Treatment method with future potential*
10:30 – 11:30	**Mr. Hironari YAMADA – Japan** *Title to be received*
11.45 – 12.45	**Mr. Bumsoo HAN – Korea, Republic of** *Requirements of Electron Accelerator for Environmental Application*
14:00-15:00	**Mr. Andrez CHEMILIEWSKI – Poland** *Accelerators for the future research, industry and environmental applications*
15.00 – 16.00	**Mr. Z.Zimek – Poland** *Reliability and availability of high power electron accelerators for radiation processing*
16.30 – 17.30	**Mr. Aleksandr Bryzgin – Russia** *ILU accelerators for EB and X-ray*

Wednesday, 9 September 2015

Session III	**Participants' Discussion : ALL PARTICIPANTS**
9:30-10:30	**Mr Urs V.LAUPPI – Switzerland** *Permanent sealed, compact ebeam engine*
10:30-11:30	**Mr Peter MCINTOSH – United Kingdom** ***Title to be received***
11:45 – 12:45	**Mr Robert Kepher – United States of America** ***Title to be received***
14.00 – 15.00	**Mr. Peng WEI - China** *The development and outlook of the EB irradiation facilities and their applications in China*
15.30 – 17.30	*Discussion "Emerging scenario of electron beam applications"*

Thursday, 10 September 2015

Session IV	**Discussion and Initiating Preparation of Technical Document;- ALL PARTICIPANTS**
09.30- 11.00	*Discussion "New generation accelerators – meeting techno-commercial needs of emerging applications"*
11.30 – 13.00	*Discussion "Strategies for enhancing deployment of EB technologies: enhancing mutual cooperation among stakeholders and the potential IAEA role"*
14.00 – 15.30	Preparation of a technical report : scope/contents/structure of the meeting report/conclusions/recommendations

		Emerging												
		Partial cross link	EBFGT	waste water	sludge	heavy oil upgrade	flare gas	highway lifetime	chip industry euv Light	ADS	catalyze chemical reactions	Medical heavy ion	Soil Remediation	surface seed treatme
	Accelerator type													
existing	low power microtron							Yes						
	DC accelerator	Yes	Yes	Yes	Yes	Yes	Yes				Yes		Yes	Yes
	table top synchrotron													
	single cavity low frequency linac	Yes		Yes	Yes	Yes	Yes				Yes			
	high frequency linac	Yes												
	conv cyclotrons											Yes		
	single cavity multi-pass (Rhodotron)	Yes		Yes	Yes	Yes	Yes				Yes			
	linac driven FEL													
	Proton linac													
evolving	high power microtron	Yes												
	compact rhodotron	Yes												
	high energy rhodotron (40 MeV)													
	high power/efficent copper linac	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Yes		Yes	
	circular light sources								Yes					
	multi-cavity low frequency linac			Yes	Yes	Yes	Yes				Yes			
emerging														
	Compact SC cyclotrons (5T)											Yes		
	Compact SRF Linacs	Yes		Yes	Yes	Yes	Yes	Yes			Yes		Yes	
	high power SRF linac (MW)			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	
	SRF Energy Recovery Linac								Yes					
New technology but utility unknown	pulsed Low energy/high current													
	laser plasma wakefield													
	beam driven plasma wakefield													
	FFAG													
	Dielectric wall													
	Integrable Optics Circular													

CONCLUSIONS

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3) Th
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１）EBの利用はは産業利用及び環境保全で増加している。

２）国やIAEAによりEB技術をラボからインダストリーへ移転する強力なプログラムが必用である。

３）ユーザーとサプライヤーの繋がりを強化する必要があり、IAEAは重要な役割を果たすことができる。

４）低エネルギーEBはインク定着、コーティング、接着剤として需要が増加している。

５）１０KW以上のEBを必要とする多くのアプリケーションが有るが、低コストで、高い加速効率を有し、簡単なオペレーションが望まれる。既存のEB装置は、パフォーマンスや、信頼性を向上させる必要がある。

６）５MeV以上で、MWクラスのEBを必要とする多くのアプリケーションがある。

７）タイヤのクロスリンキングや種子表面の殺菌、農地の滅菌、排水の滅菌において、開発途上国で大きな需要がある。

8) The … ations:
industri…
remedi…
9) Sm… velop
applica…
10) La… ne
majority … ator
builders … es of
Americ…
Progra…
11) Re… ke
superc…
develo… h
power, …
operati…
12) Th… cilities
and rad… s.

8）移動式のEB装置に需要が有る。汚染水の処理や環境の保全には移動式が必用である。

9）移動式のEBや小型EBはさらに需要を探すことができる。

10）多くの国で、ビッグサイエンスで加速器に巨大な予算が付けられている。そして、多くの場合、産業とラボのコネクションは強いとは言えない。

11）超電導リナックの様な革新的な加速器技術は加速器の小型化や低コスト化に貢献すると思われる。

12）IAEAは産業用加速器プロバイダー、放射線化学ラボと繋がりがあるが、もっと強化するのが良い。

http://www-pub.iaea.org/iaeameetings/50814/ICARST-2017

Target Audience

Radiation science and technology is a multidisciplinary area that covers many branches such as radiation-related physics, chemistry, materials science, biology, engineering and industrial applications. Accordingly, the target audience for this conference comprises but is not limited to:

- Radiation technology professionals
- Entrepreneurs or stakeholders involved in applications of radiation technologies
- Research scientists engaged in radiation research
- Policy makers and regulators

Participation and Registration

No registration fee will be charged to participants. The IAEA is generally not in a position to bear the travel and other costs of participants in the conference. The IAEA has, however, limited funds at its disposal to help meet the cost of attendance of certain participants.

All persons wishing to participate in the conference are requested to register online in advance through the conference web page and send a completed Participation Form (Form A), and if applicable, the Form for Submission of a Paper (Form B) and the Grant Application Form (Form C) to their competent national authority (e.g. Ministry of Foreign Affairs or National Atomic Energy Authority), or to one of the organizations invited to participate, for subsequent electronic transmission to the IAEA (**Official.Mail@iaea.org**).

Working Language

The working language of the conference will be English.

Key Deadlines

Submission of abstract (including Form A and B)	**30 June 2016**
Submission of Grant application (Form A and C)	**30 June 2016**
Notification of Acceptance of abstract	**End of July 2016**
Submission of full papers	**end of October 2016**

Submission of Abstracts

Abstracts must be sent in electronic format (no paper copies) directly to the IAEA. Instructions on how to upload the abstracts to the conference's web browser-based file submission system (IAEA-INDICO) will be available on the conference web page as of February 2016. No other form of submission will be accepted.

Exhibition

A limited amount of space will be available for commercial vendors' displays/exhibits during the conference. Interested parties should contact the Scientific Secretariat by email at: **icarst2017@iaea.org** by 30 June 2016.

Scientific Secretary

Mr João Alberto Osso Júnior
Division of Physical and Chemical Sciences
Department of Nuclear Sciences and Applications
Tel.: +43 1 2600 21748
Email: icarst2017@iaea.org

Administration and Organization

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Conference Services Section
Division of Conference and Document Services
Department of Management
IAEA-CN-249
Tel.: +43 1 2600 21321
Email: J.Zellinger@iaea.org

Conference Web Page

www-pub.iaea.org/iaeameetings/50814/International-Conference-on-Applications-of-Radiation-Science-and-Technology-ICARST-2017

ICARST2017

International Conference on Applications of Radiation Science and Technology (ICARST-2017)

IAEA Headquarters
Vienna, Austria
24–28 April 2017

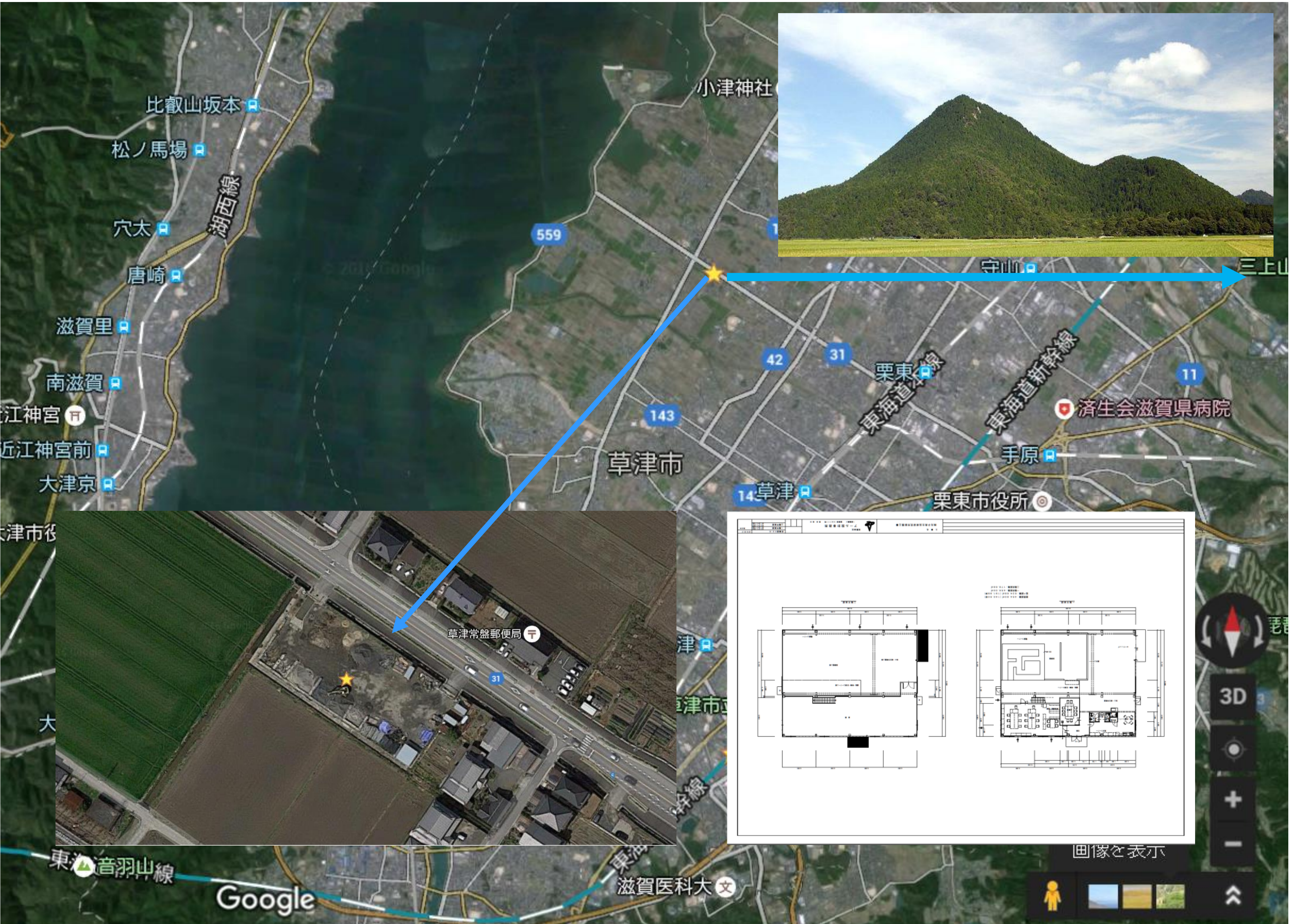
IAEA
International Atomic Energy Agency
Atoms for Peace

IAEA-CN-249

The scope of the conference is meant to cover, but is not limited to, the following topical areas:

- Recent advances in radiation chemical sciences
- Current radiation technology trends
- Setting up of new radiation facilities
- Production and transportation of cobalt-60
- New generation electron beam accelerators and X-ray sources
- Radiation sterilization
- Radiation modification of polymeric materials
- Radiation chemistry in the synthesis and design of nanomaterials
- Development of advanced materials using radiation technology
- Surface curing using radiation technologies
- Radiation treatment of gaseous pollutants, industrial wastewaters, municipal wastewater, sludge and emerging organic pollutants
- Use of radiation technology for cultural heritage imaging and preservation
- Radiation chemical aspects related to water coolant systems in nuclear reactors, fuel reprocessing and nuclear waste management
- Operational experience from radiation facility operations
- Radiation dosimetry
- Implementing quality management practices for the control of radiation processes
- New generation safety and control features in radiation facilities
- Applications of tracers and radiotracers for studying industrial and environmental processes
- Thin layer activation method for wear measurement
- Nucleonic control and measurement systems
- Radiation detection techniques and equipment
- Computational fluid dynamics and numerical modelling of residence time distribution
- Radiation based imaging technologies
- Economic aspects of radiation technologies vis-à-vis conventional technologies
- Educational tools and methods for human resource development in this field

実用の時代を迎えた
卓上型放射光装置



比叡山坂本
松ノ馬場
湖西線
穴太
唐崎
滋賀里
南滋賀
近江神宮前
大津京
559
小津神社
守山
三上山
42
31
栗東
東海道新幹線
11
済生会滋賀県病院
143
草津市
手原
草津
栗東市役所
草津常盤郵便局
31
音羽山
滋賀医科大
画像を表示
3D
Google

光発生技術で未来を拓く 光子研

Photon Production Laboratory, Ltd. www//htpp/photon-production.co.jp

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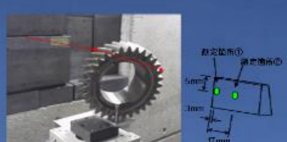
卓上型シンクロトロンでハイパワー放射光を実現
遠赤外線、EUV、軟X線、硬X線、MeV領域γ線の利用が可能
微細構造の分析は光子研にお任せください
新しい分析・検査手法を提案いたします

金属内部の残留応力を測定します

残留応力は、表面ではゼロでも内部に蓄積します



中性子を使わなくても軽元素・重元素の密度分布がわかります

チタンとチタン酸化物の違いを識別・セラミックスの品質管理に最適

産業用CTで0.3mm解像度を実現

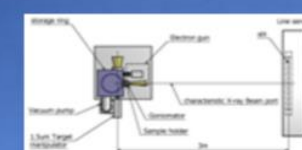
解像度0.3mmでSTLデータを出力します自動車の大型部品や蓄電池・燃料電池の欠陥解析に威力を発揮

60cm厚コンクリートの診断を行います

床版の検査を深さ30cmまで可能にする研究を進めています

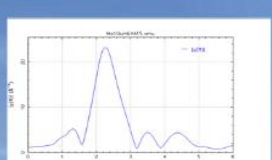
サブミクロンX線顕微CT装置を開発中

従来装置で2時間かかる撮影を10分で行います



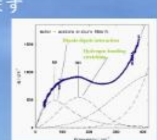
EXAFSで化学状態を分析します

蓄電池材料や触媒の開発に威力・環境化学物質の分析にも適しています



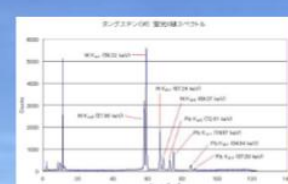
水溶液のテラヘルツ分光が可能な民間で唯一の装置です

テラヘルツ放射パワーは大型放射光を凌ぎます



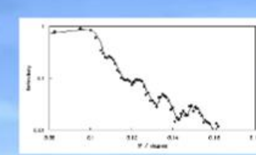
全元素の蛍光X線分析をPPMオーダーで実現

TXRF(全反射法)を用います



小角散乱で粒子サイズや膜厚がわかります

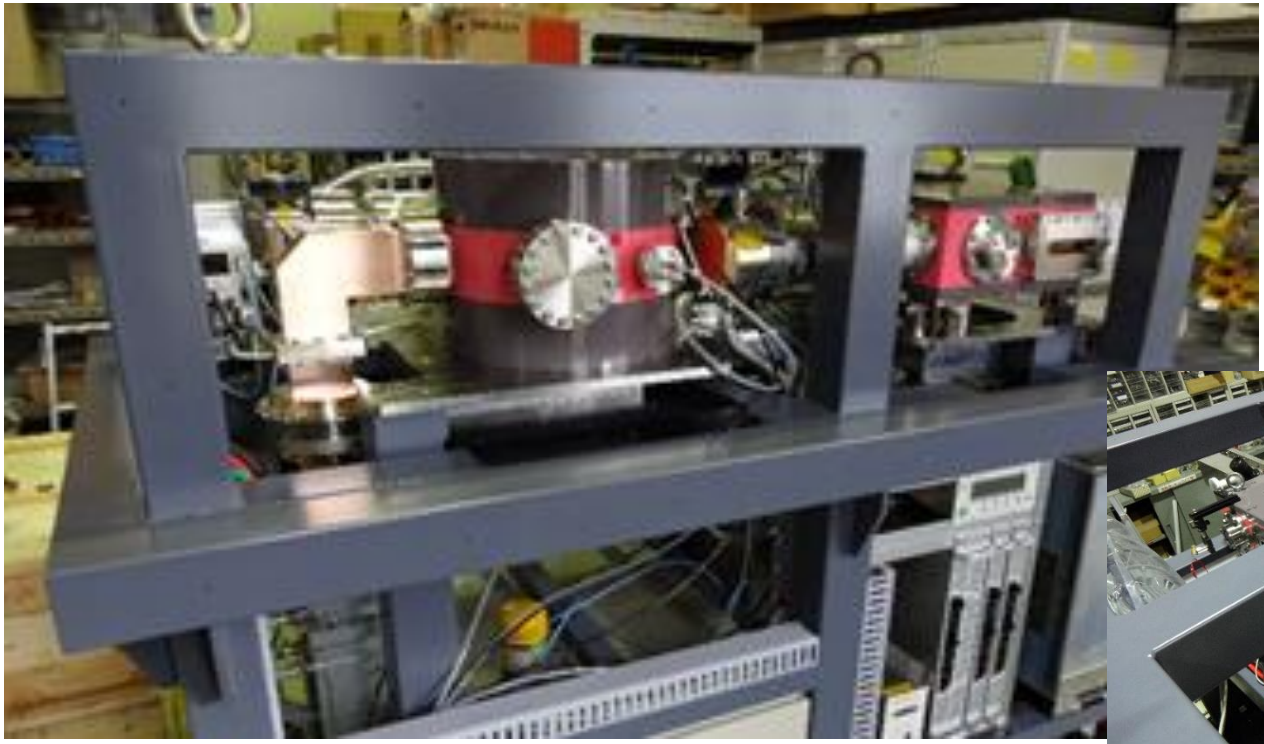
タンパク質の形状測定にも利用できます

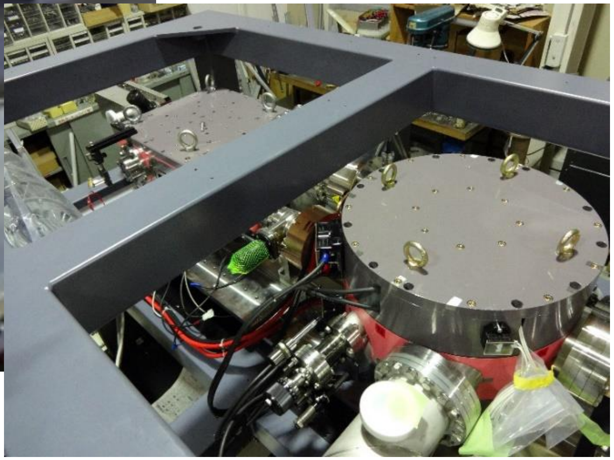


マイクロトロンは小型ハイパワーの滅菌・殺菌装置に最適です

10MeV-40kWの滅菌装置を提供します

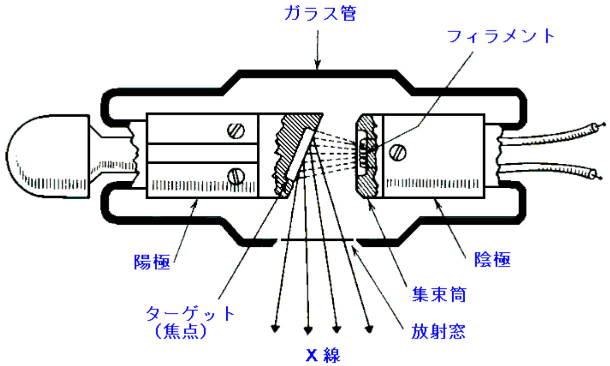
The latest machine MIRRORCLE-CV4 HP model produced last year for HITACHI Ltd.





MIC1-CT system installed in a factory

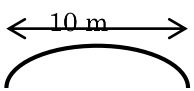
MIRRORCLEのX線発生機構



エックス線管の構造

蛍光X線は原子が放出するので360°方向に出る

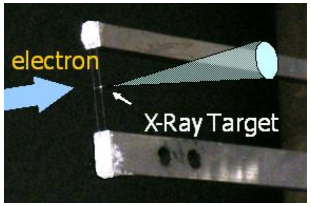
大電流ではターゲットが溶けるため、X線フラックスには限界がある。

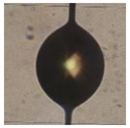


磁場で電子を曲げて制動放射を発生

ターゲットのクーロン力で電子を曲げて制動放射を発生

ターゲットが微小であるため発熱が起こらない。





1．数keVから数10MeVまでの連続X線を発生

　分光して様々な高度分析を実現　XAFS,小角散乱、残留応力測定

　透過力の高いX線で非破壊検査が可能

2．世界最小光源点を実現

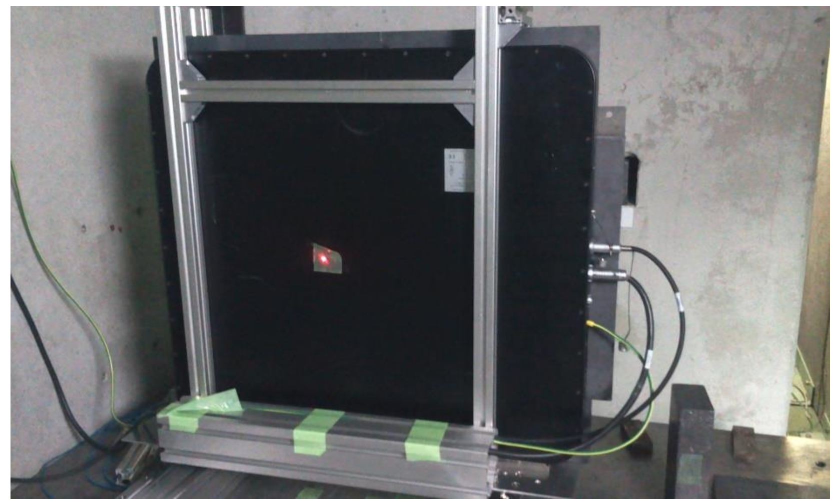
　ミクロンサイズの解像度でCTが可能

3．大きな発散角

　大型構造物の非破壊検査が可能

　高精度医療診断を実現

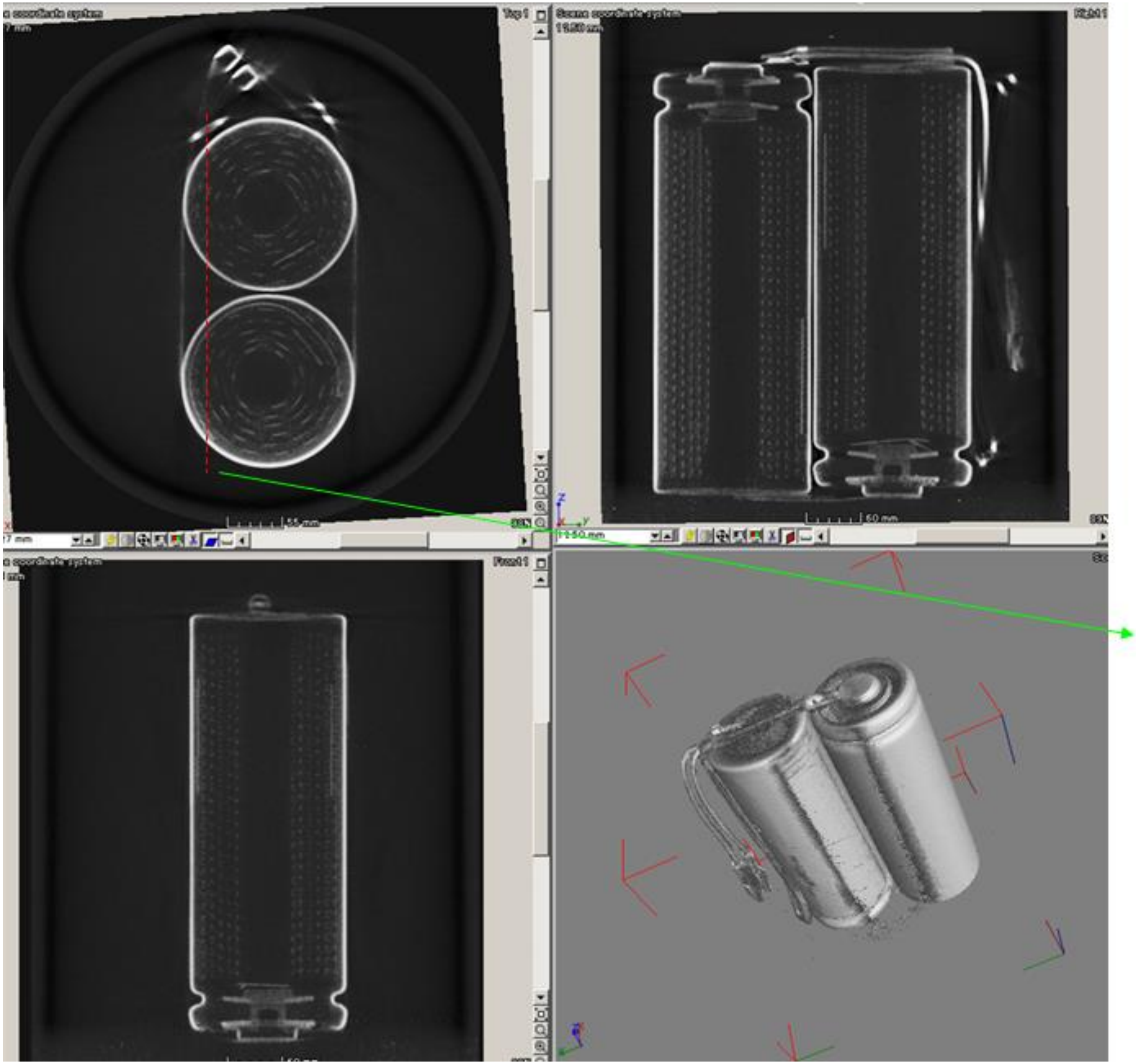
X-ray CT system



Flat panel detector

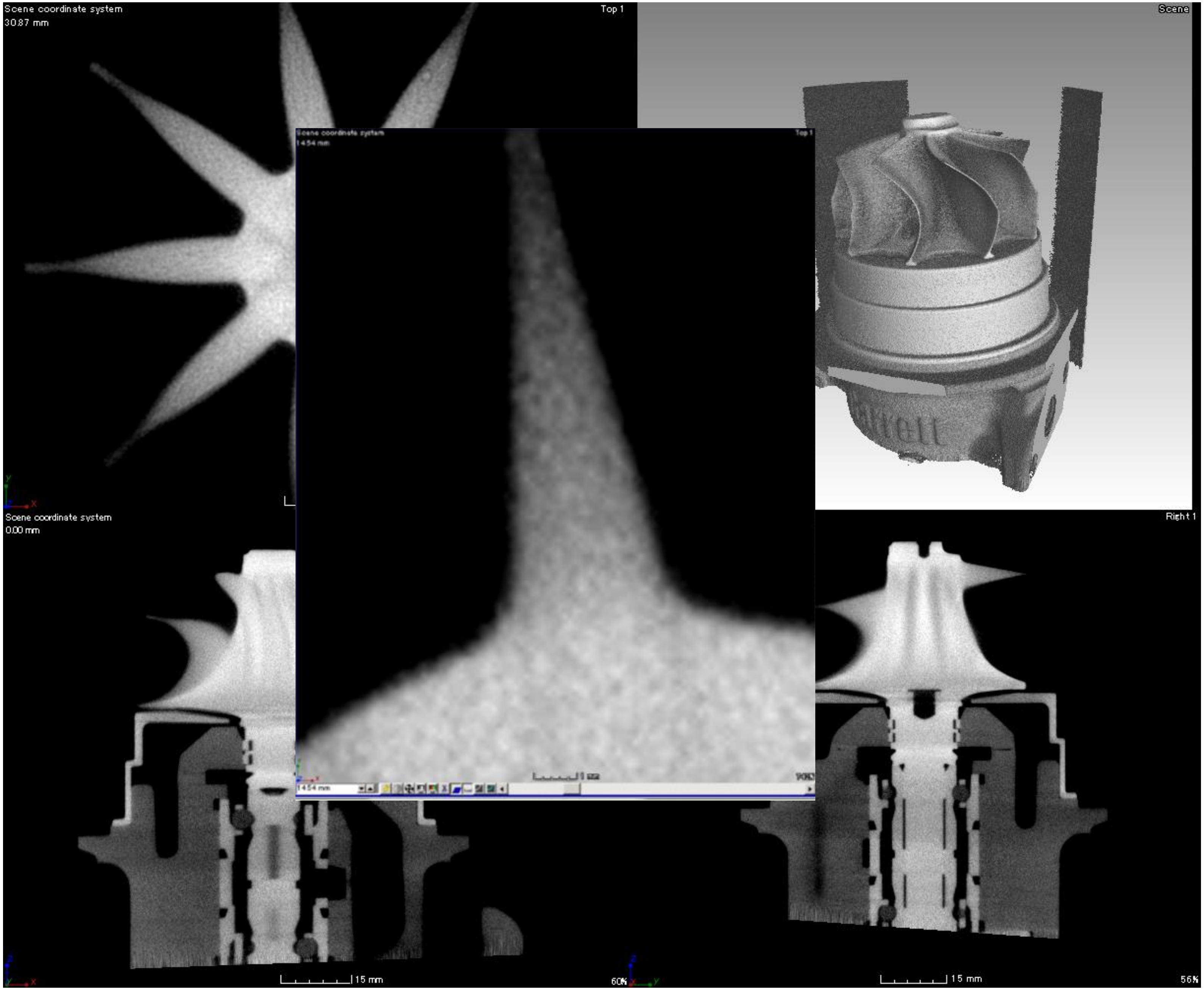
Li電池のCT

500Hz, 200mA
Target : W39s
S-O：550 mm
S-D：2600 mm
FP 1sec./frame
360° / 600 frame

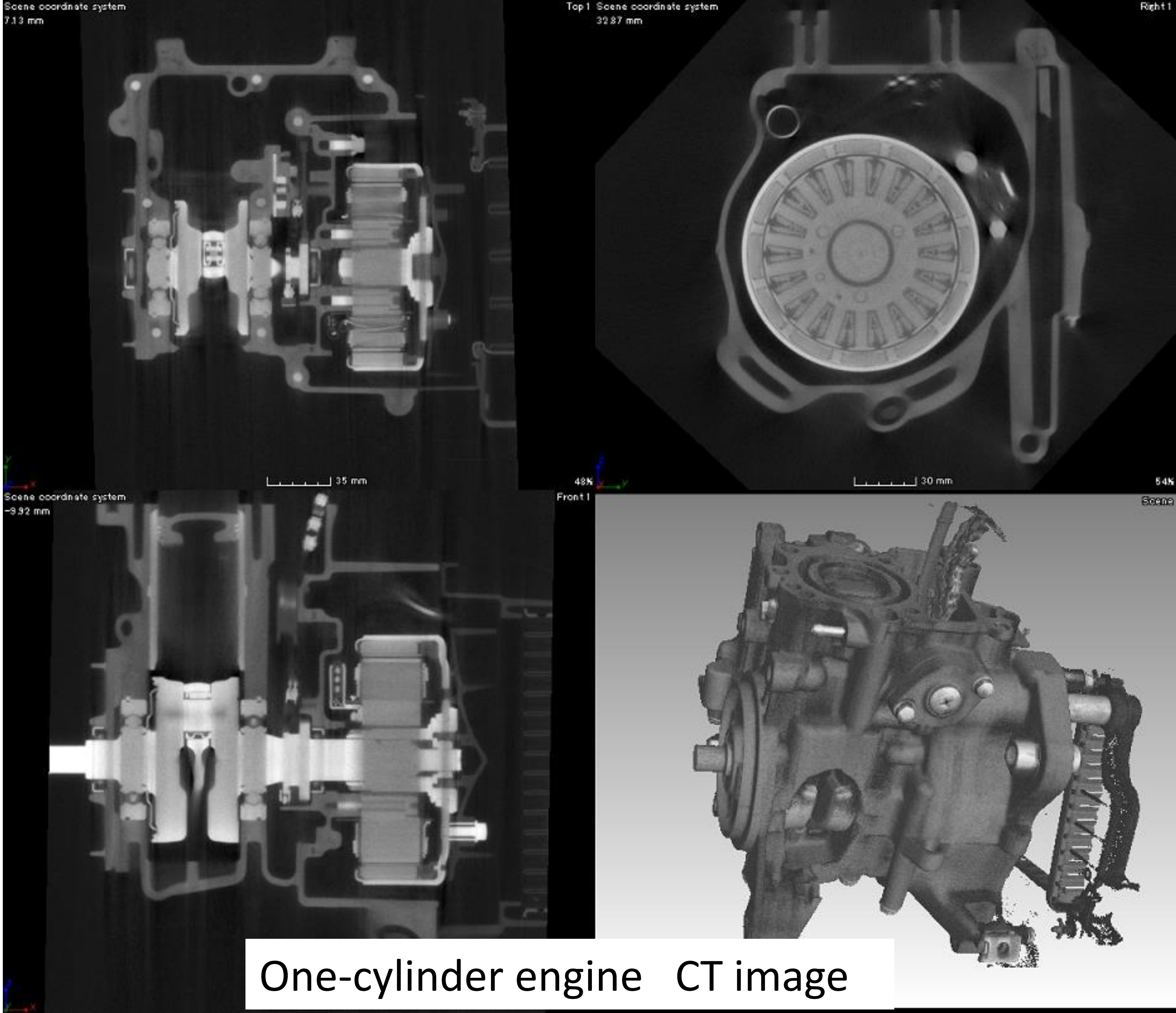


内部の電極の様子がかなりきれいに撮影できた。

内部電極が網目状になっていることも確認。

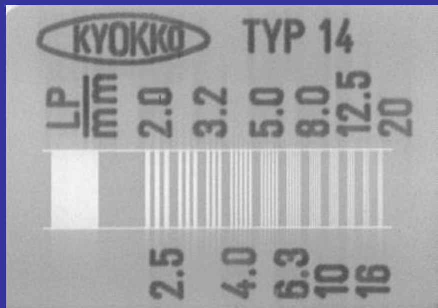


Scene coordinate system
30.87 mm
Top 1
Scene
Scene coordinate system
0.00 mm
Right 1
15 mm
60%
15 mm
56%

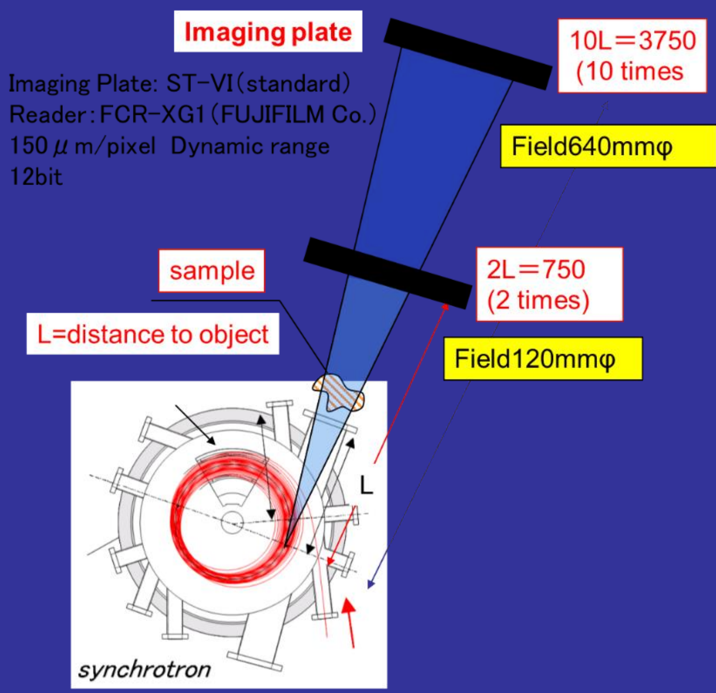


One-cylinder engine   CT image

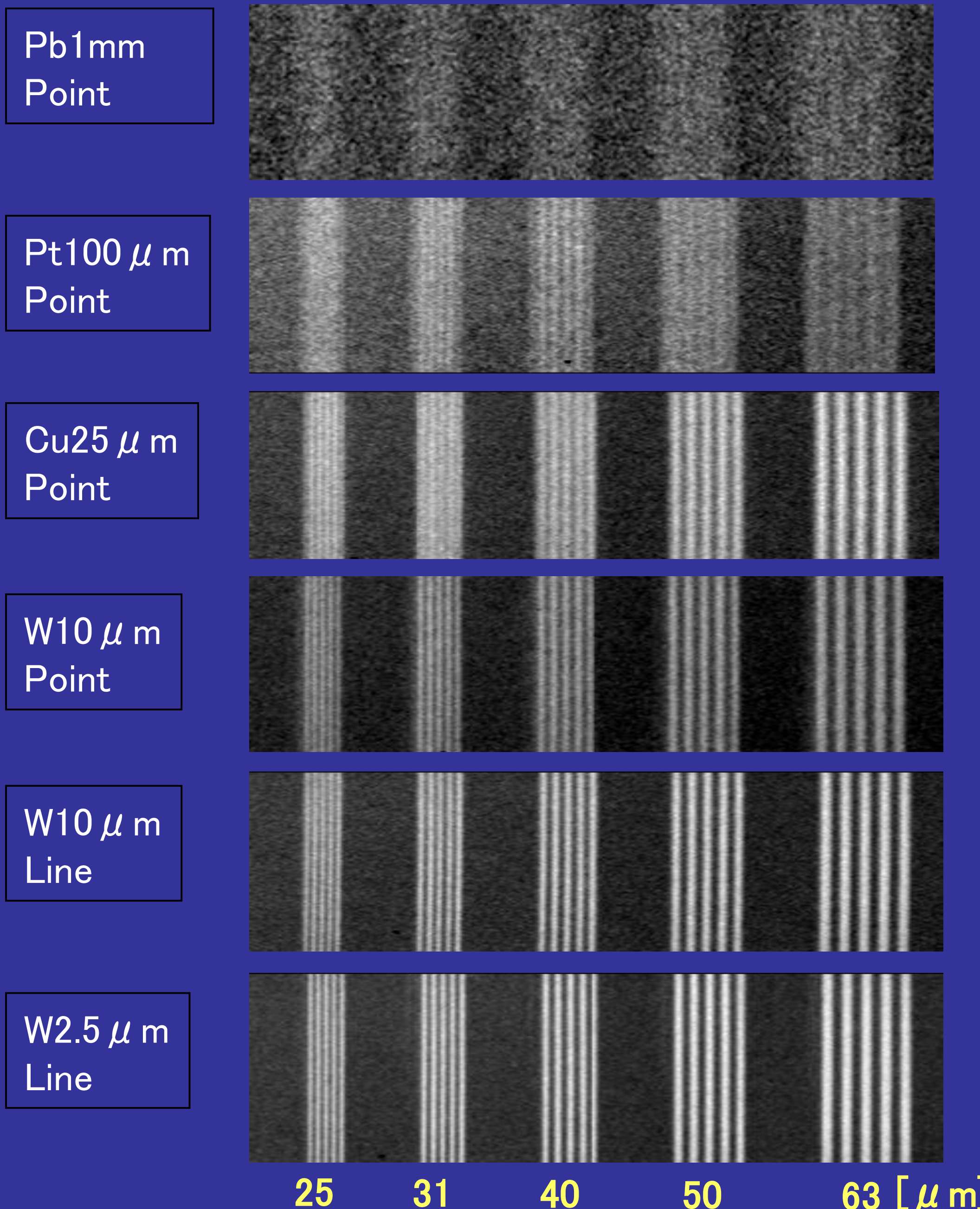
MIRRORCLE-6Xの解像度測定



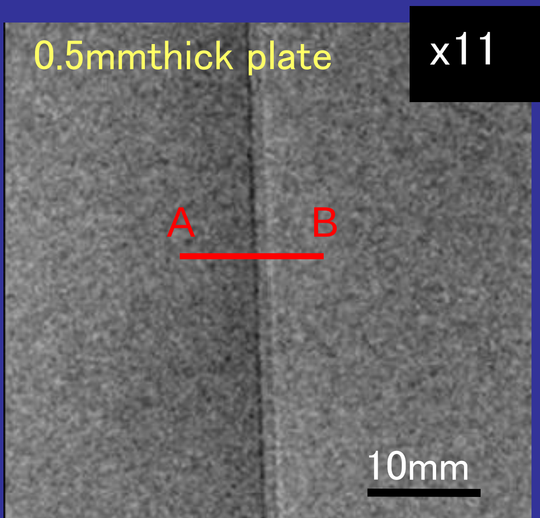
11倍拡大

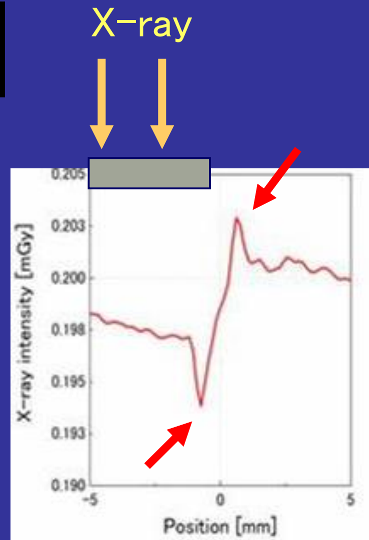


検出器:150μm/pixel イメージングプレート



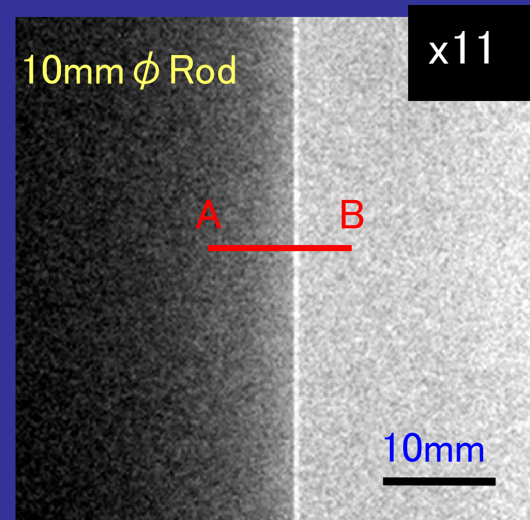
Shape dependence of edge effect

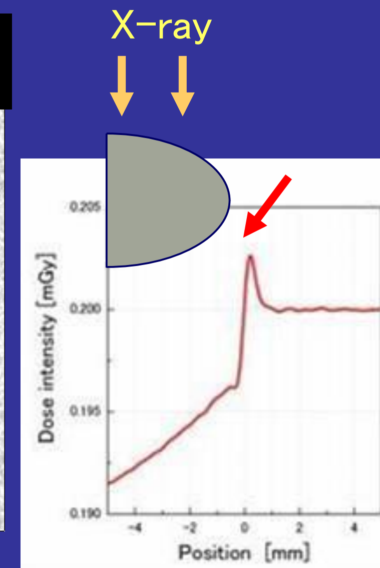




Plane sample

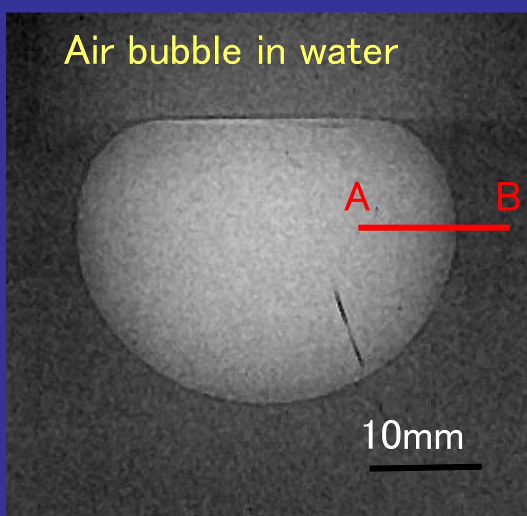
target：W10 μ m φ Wire

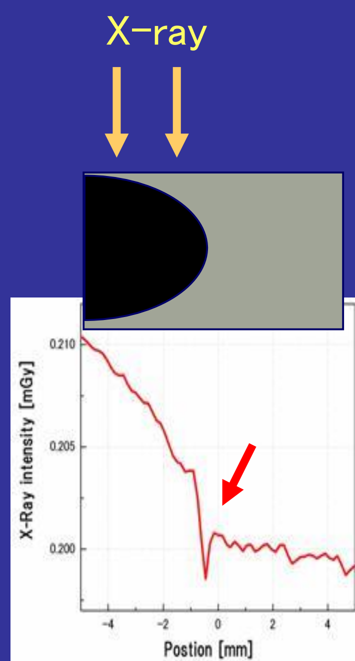




凸shape

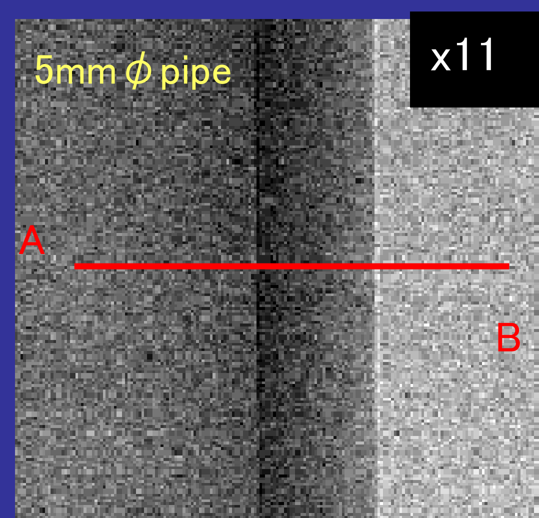
target：W10 μ m φ Wire

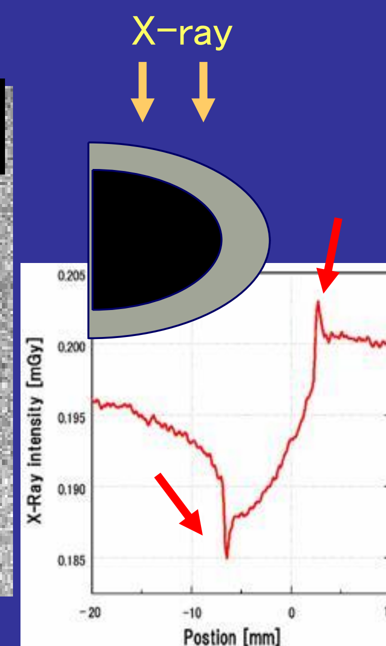




凹shape

target：Cu25 μ m φ Rod

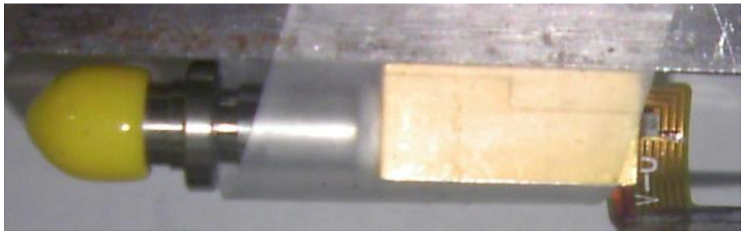


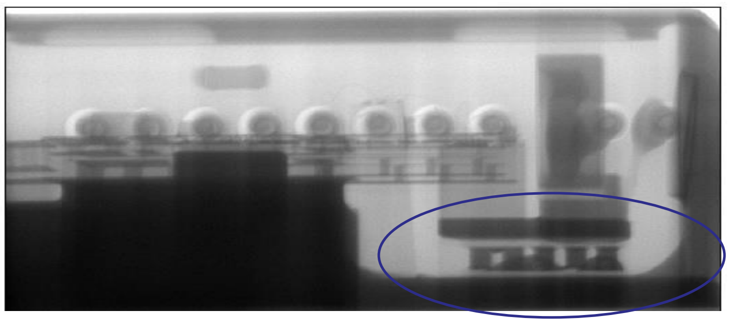


凹凸shape sample

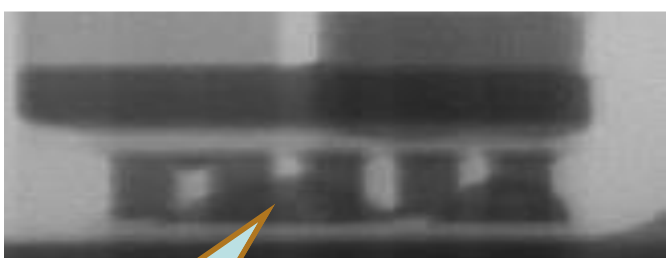
target：W10 μ m φ Wire

非破壊検査事例

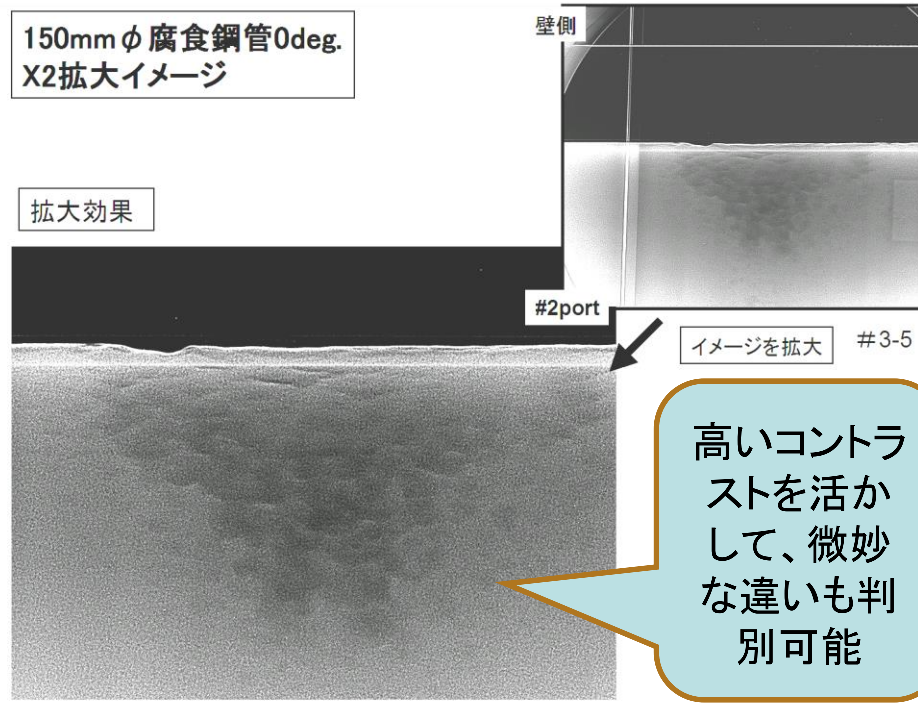




ペルチェ素子



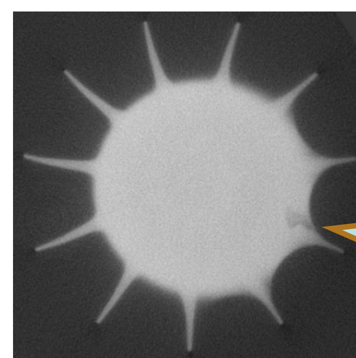
金属内部の
接着剤が見える



高いコントラストを活かして、微妙な違いも判別可能

金属配管の腐食部分の撮影

Ti製 タービンブレード

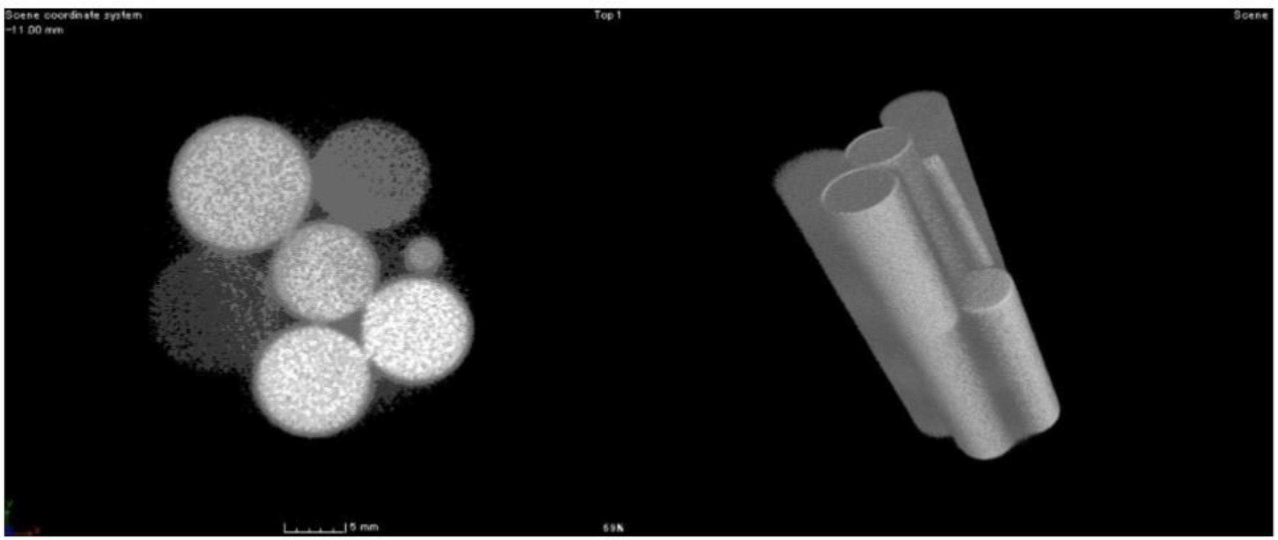


窒化チタンが見え見える
密度差を識別

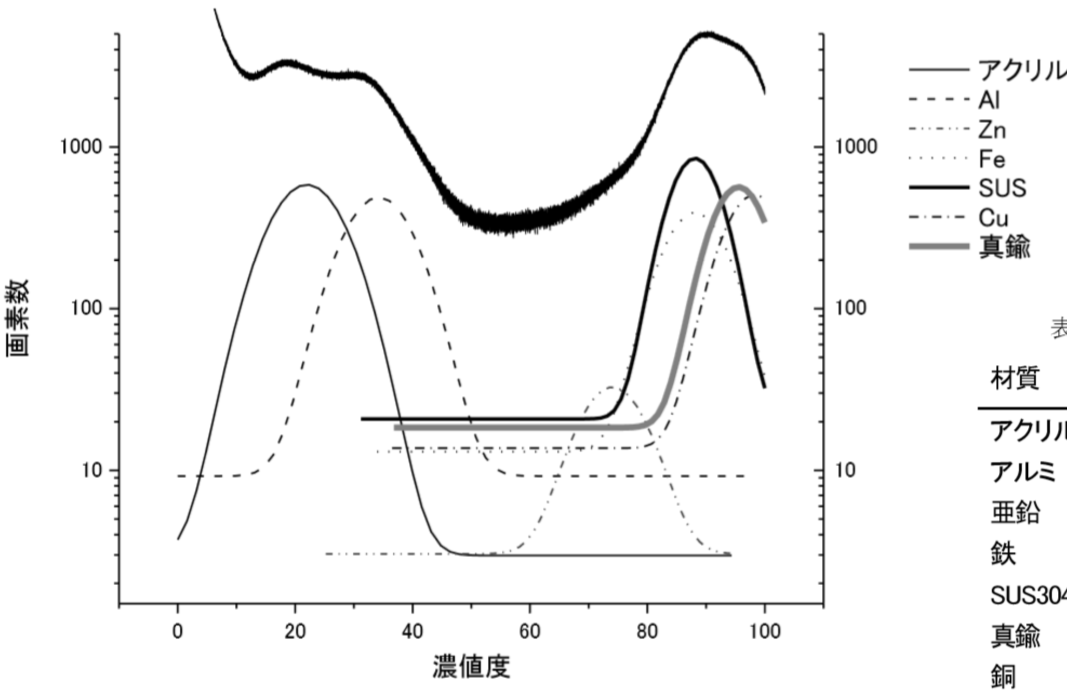
密度分布測定

CT 撮影など X 線を用いた透過画像では、密度差はコントラストの差として表れる。通常の透過画像では被写体の厚みの情報も含まれるため、単純にコントラストの差が密度差であるとは断定できないが、CT 撮影の場合は断層画像を取得できるため、コントラストを比較することで、それぞれの密度を算定することができる。

実際に MIC6-CT システムでどの程度の密度分解能があるかを評価した。サンプルには 7 種類のロッド(アクリル、アルミ、亜鉛、鉄、SUS304、真鍮、銅)を束ねて一度に撮影を行った。その CT 撮影結果を第 2 図に示した。第 2 図はロッドの断面図と 3D 画像である。



第 2 図　異種ロッドの CT 撮影結果



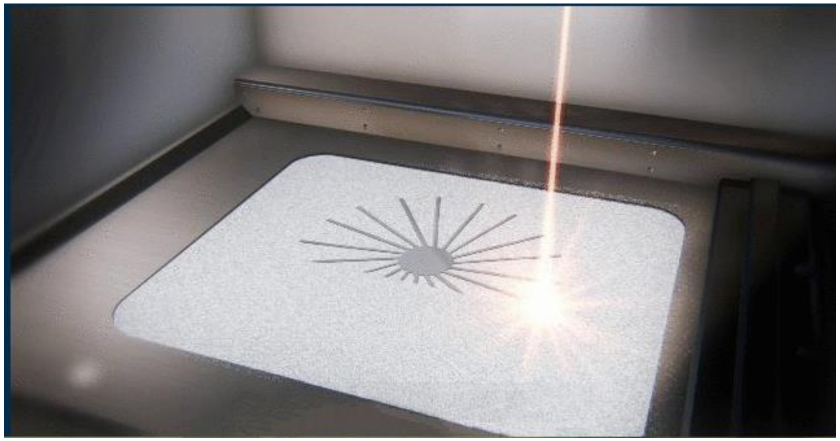
第３図　ロッドのCT画像から得られたグレイバリューのヒストグラム

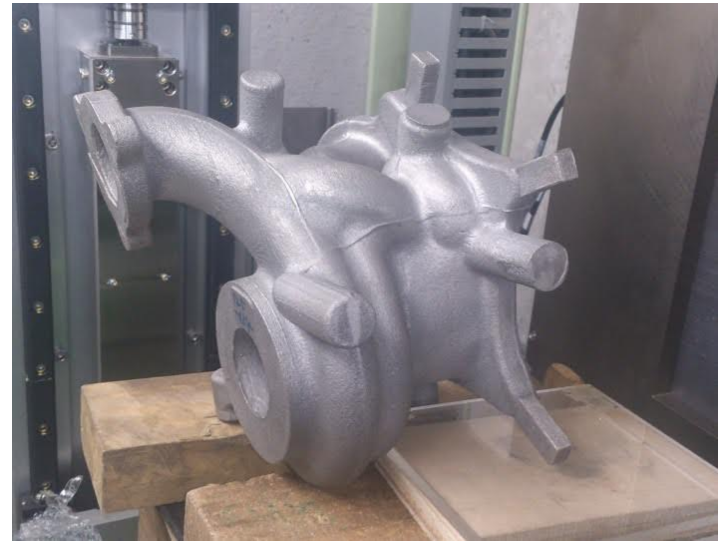
表１　材質の違いによるCT画像のグレイバリューの比

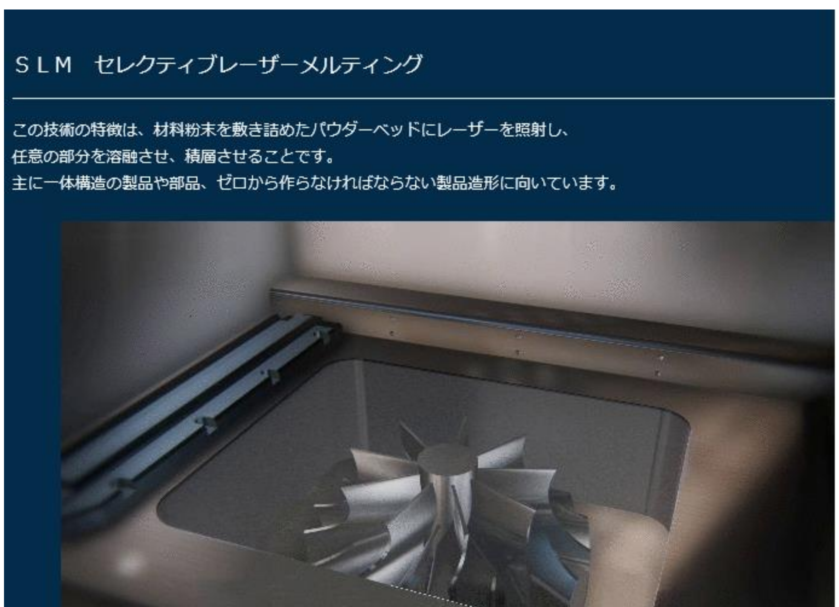
材質	密度 / g/cm³	密度の比	グレイバリューの比
アクリル	1.2	0.13	0.22
アルミ	2.67	0.3	0.35
亜鉛	7.14	0.8	0.76
鉄	7.8	0.88	0.9
SUS304	7.9	0.89	0.9
真鍮	8.5	0.96	0.98
銅	8.9	1	1

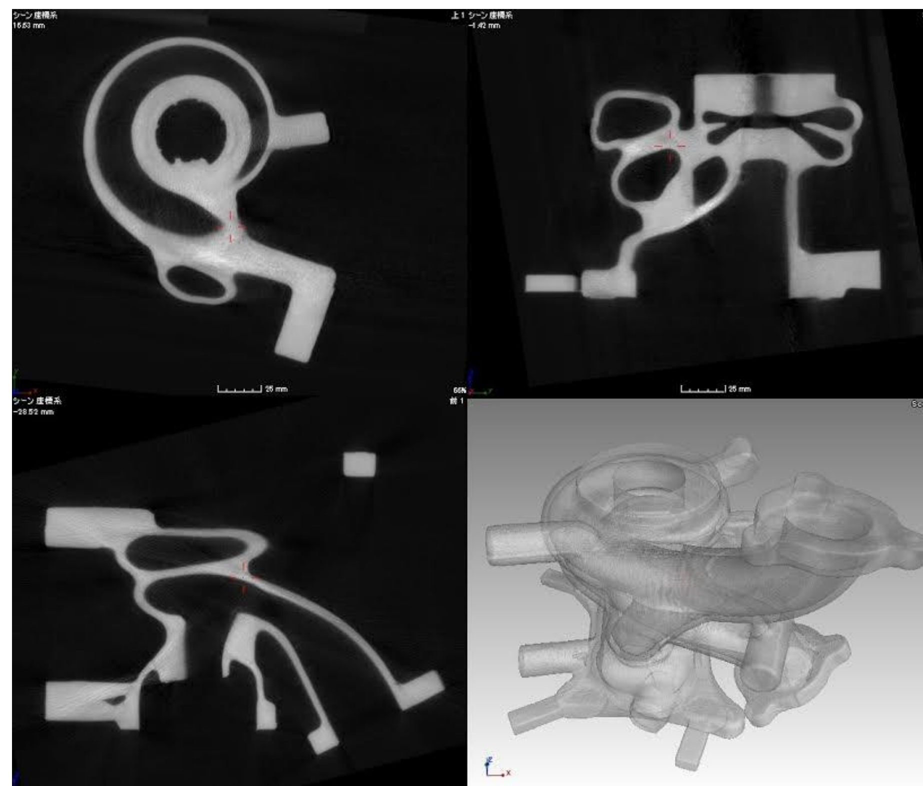
コンプトン散乱は、電子密度に依存しZには依らないので、密度測定に適している

第3次産業革命が始まっている





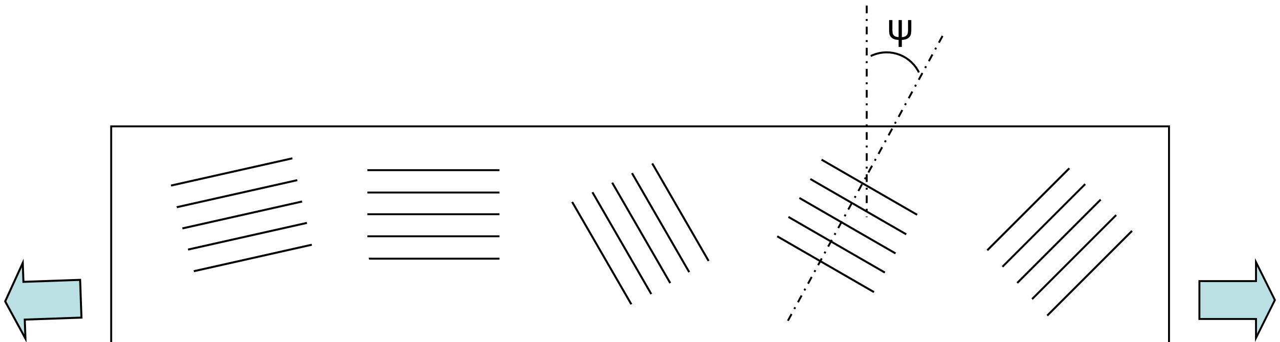




材料深部の残留応力測定実施例

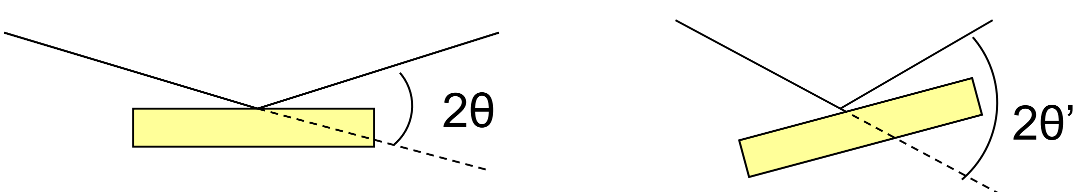
X線残留応力測定原理

X線回折法を用いて、材料の回折ピークを観測し、
材料の向きを変化させたときのピークのシフト量から残留応力を求める。



多結晶では微結晶がランダムにあらゆる方向を向いている

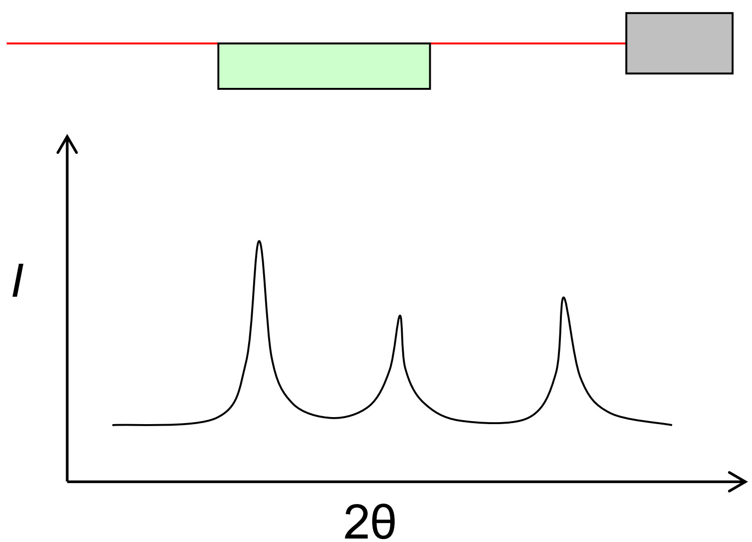
応力が加わると… 面間隔が変化



同じ面の回折光を測定しても
2θの値が変化する

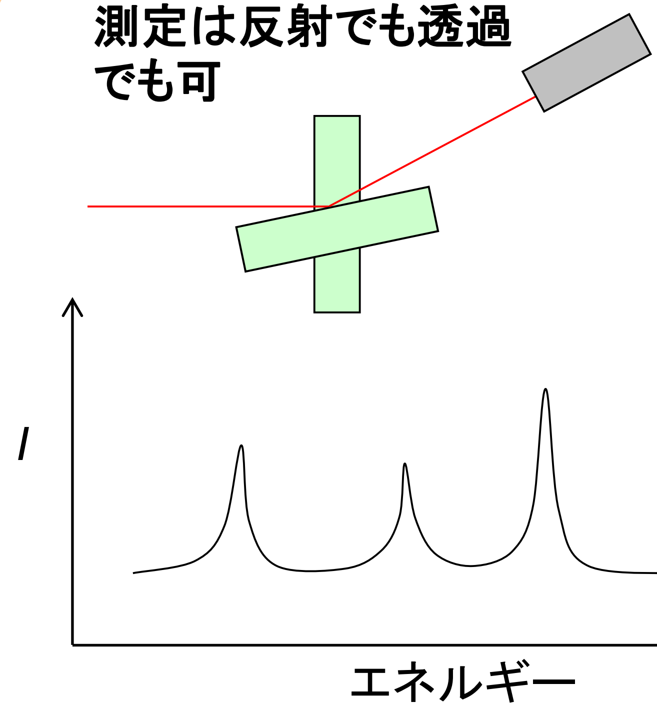
変化の割合から残留応力が
求まる

波長分散



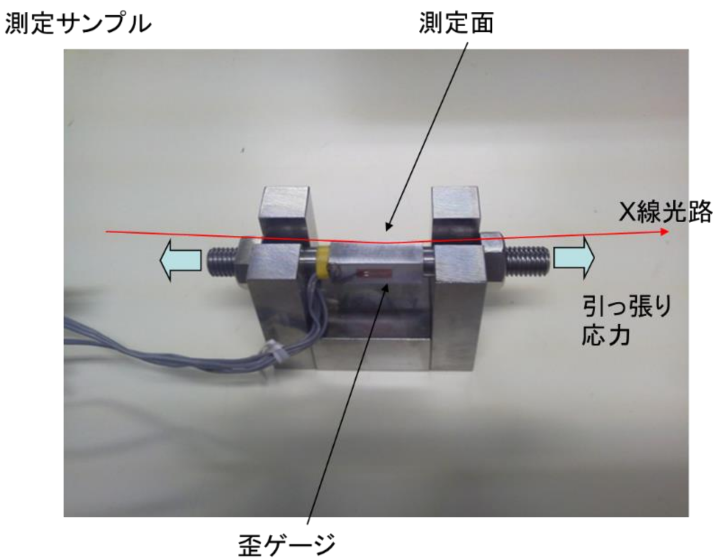
波長λのX線を角度ごとにカウント

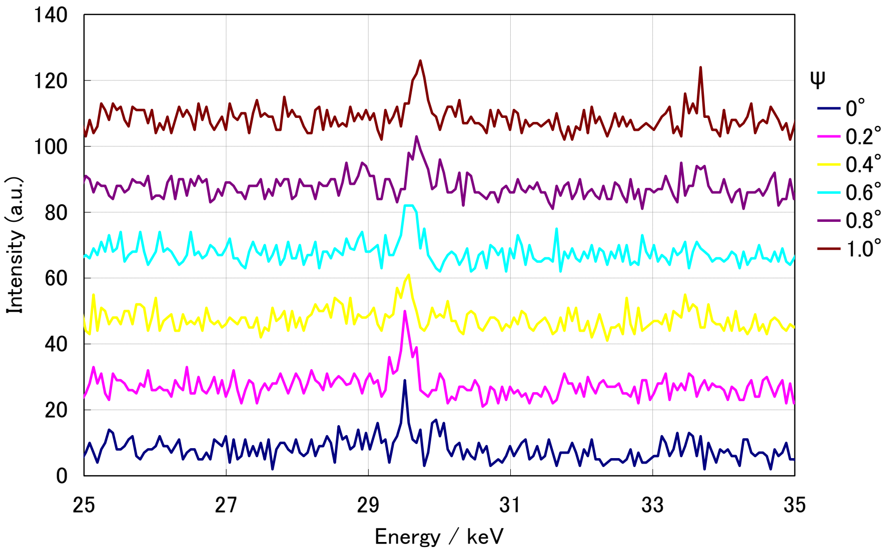
エネルギー分散

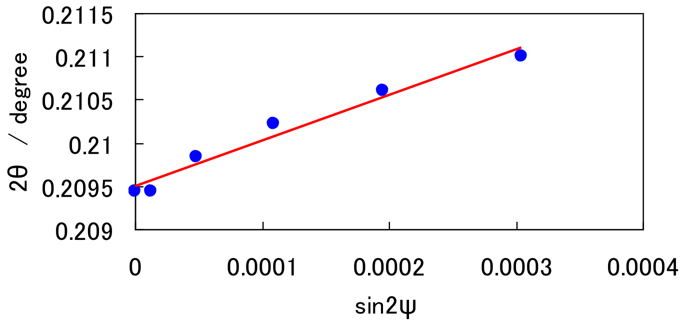


あるの角度でのX線のエネルギー
および強度を測定

ストレインゲージで応力を図りつつX線回折方を適用して、



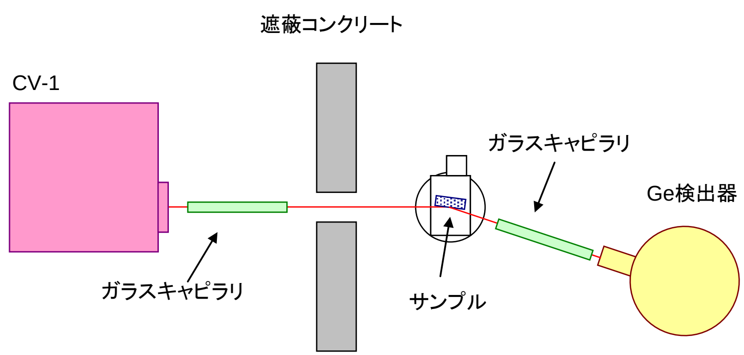




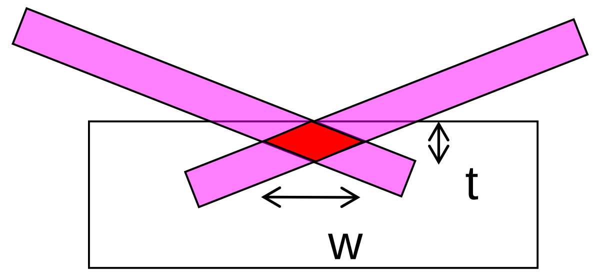
MIRRORCLEを用いた結果：43.2 MPa

歪みゲージの測定結果：　41.6 MPa

深部の残留応力評価

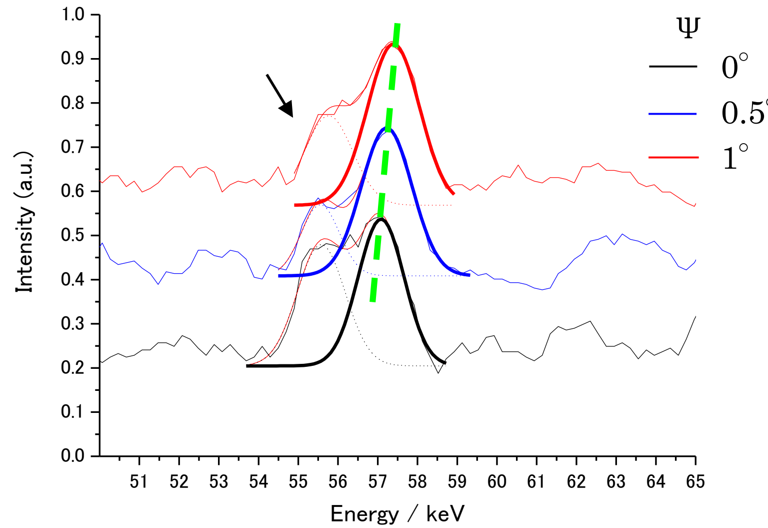


測定している箇所



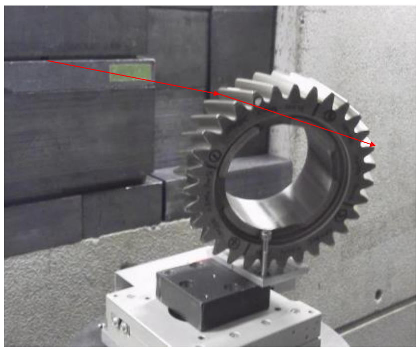
2θ：2.4°
ビーム幅：500um
の場合、

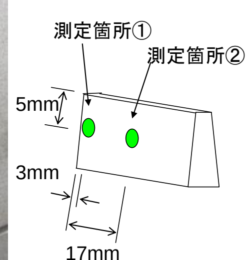
t≒20um
w≒500um

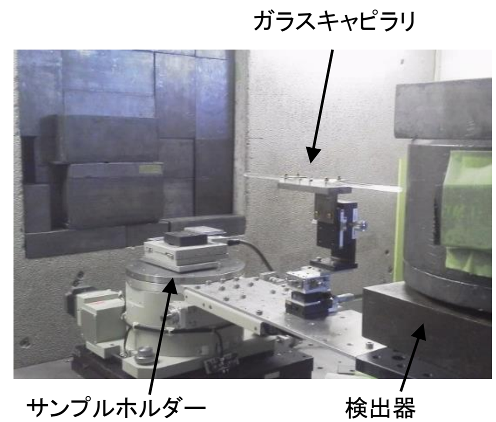


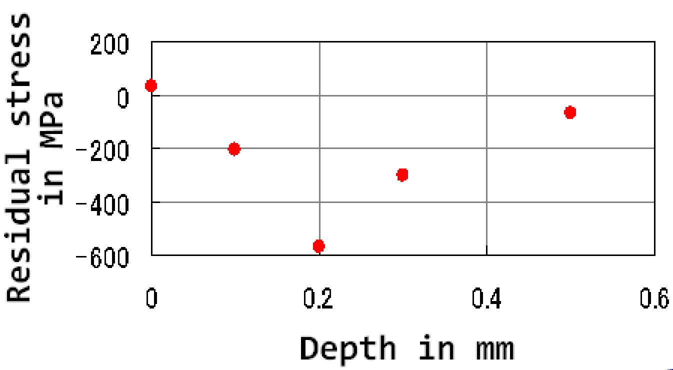
テストピースによるFe(110)回折ピーク

歯車の残留応力測定



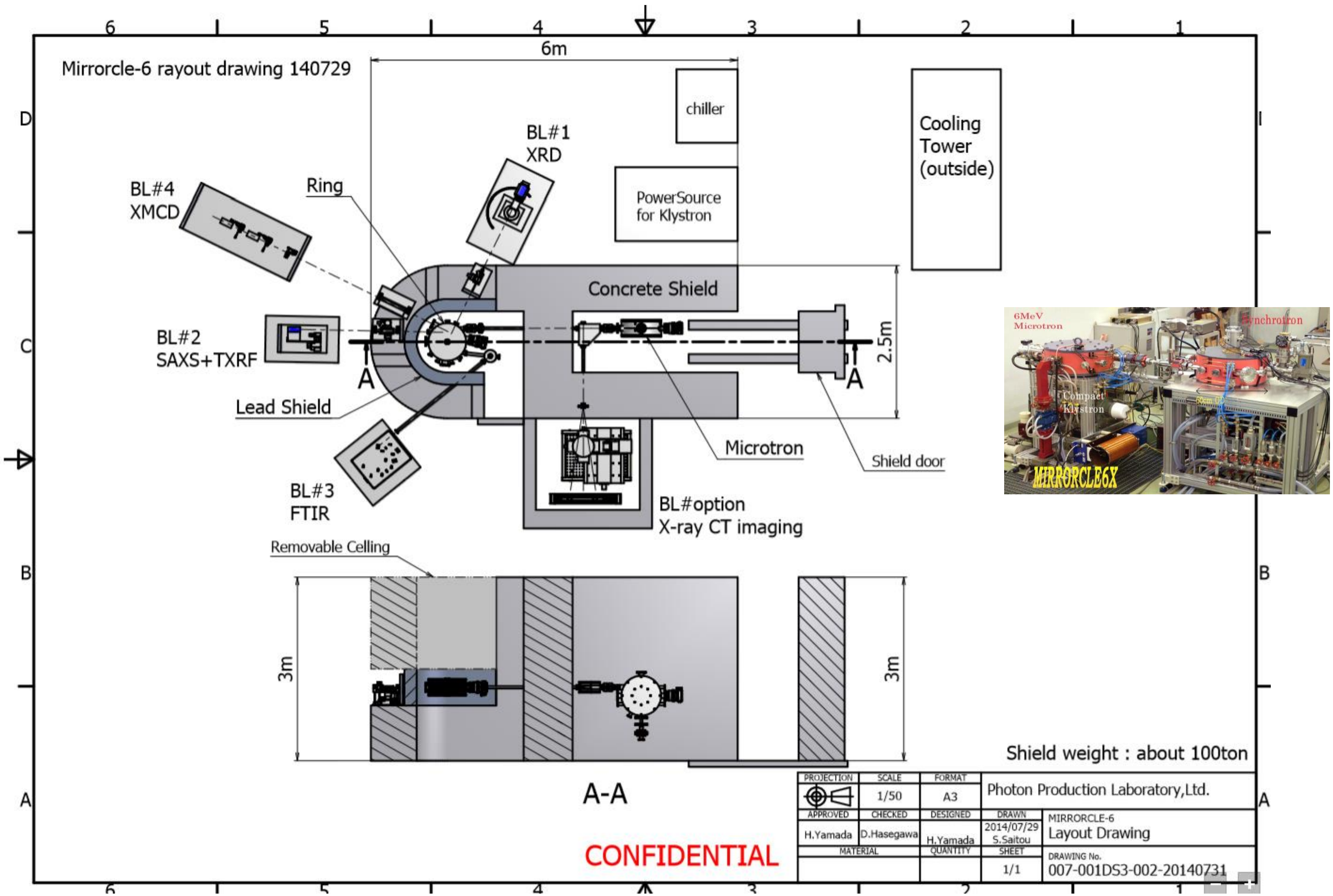






Photon Production Laboratory

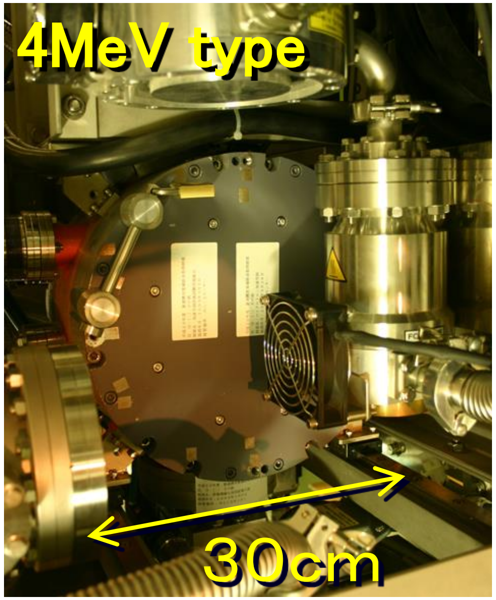
MIRRORCLE-6XHP

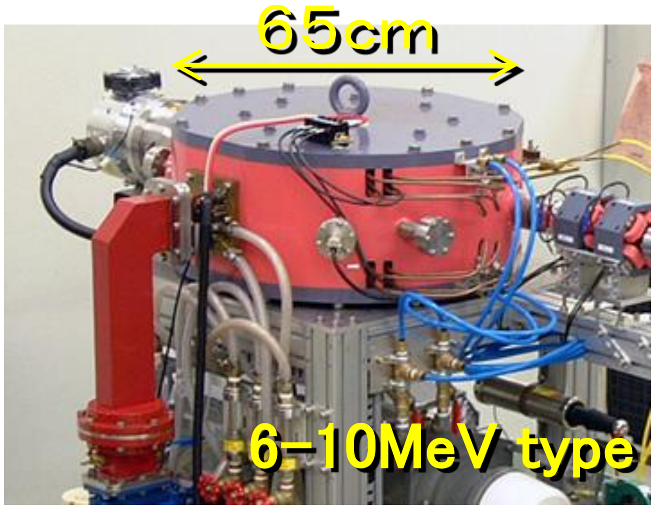


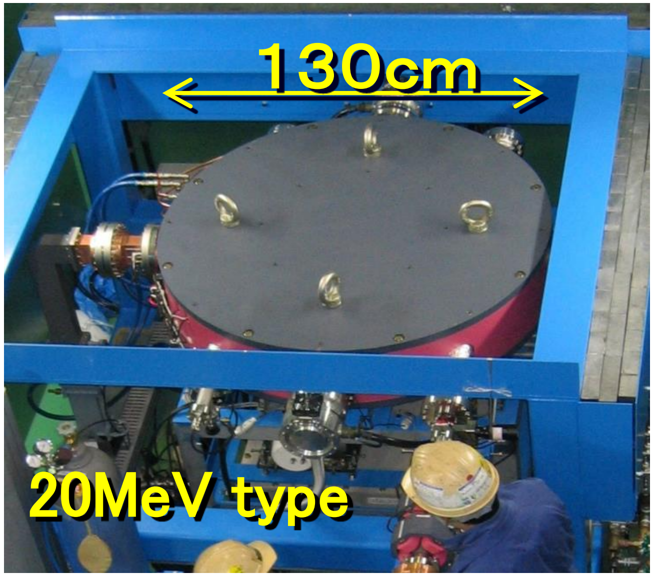
マイクロトロンの特長

Photon Production Laboratory Co. Ltd.

MICROTRON is high quality and compact accelerator

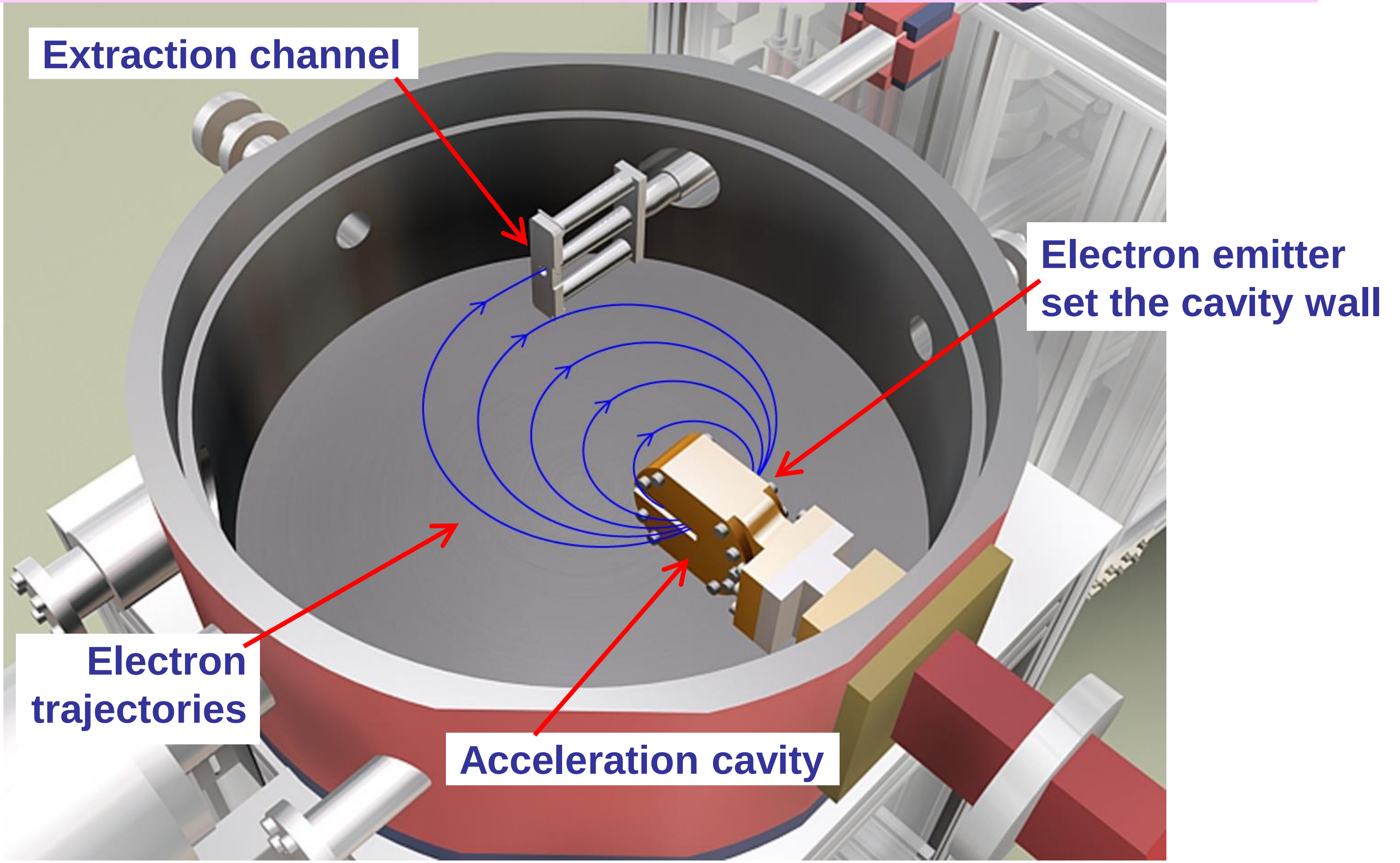






We are experienced with 1 to 20 MeV MICROTRON as an injector of synchrotron

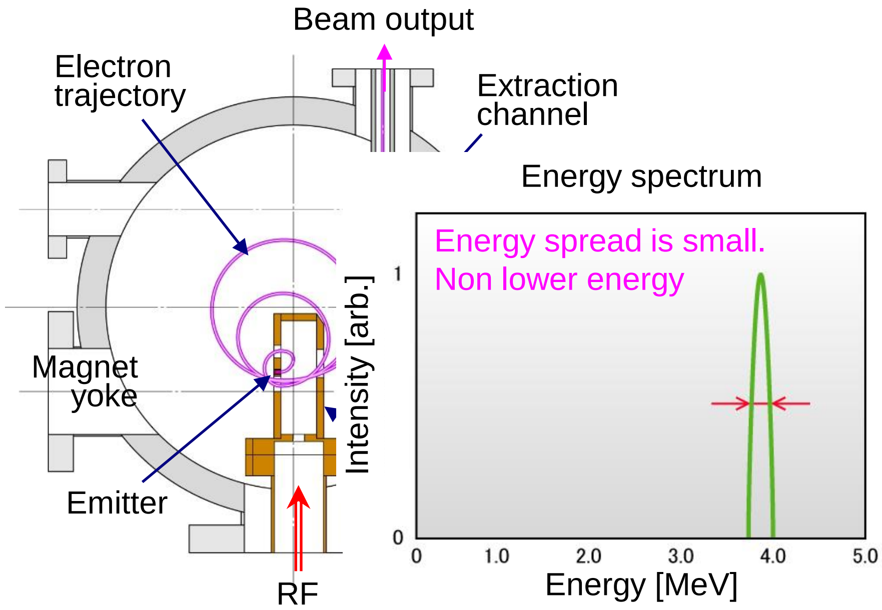
Principle of MICROTRON



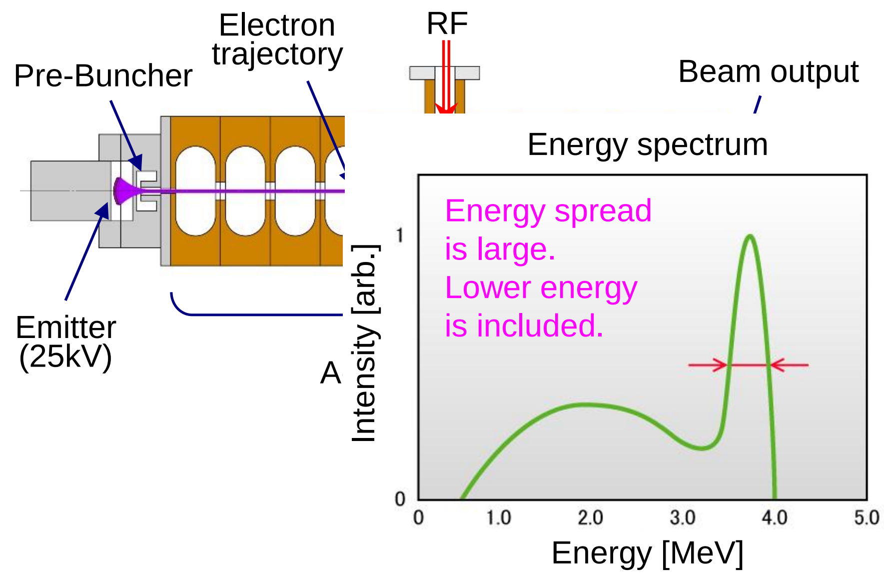
Electrons are accelerated through the cavity circulating under the uniform magnetic field and extracted to the outside when they reach the designed energy.

Comparison of microtron and linac

4MeV MICROTRON



4MeV LINAC

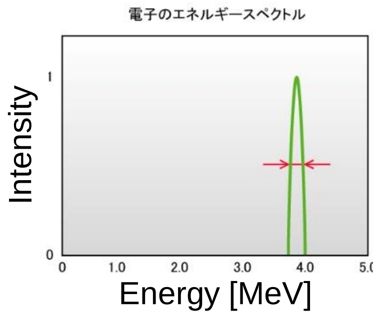


4MeV MICROTRON
1) Electrons are emitted by RF gun.
2) Electrons circulate under the uniform magnetic field and are accelerated passing through the cavity.
3) Electrons are extracted by the magnetic shield channel after reaching the designed energy.
*Electron energy is defined by the geometry between acceleration point, extraction channel and magnetic field.
*Lower energy electrons are not extracted.
*Energy spread is less than 1%.

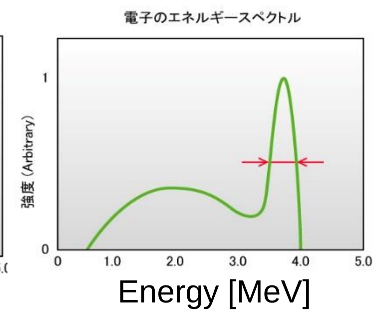
4MeV LINAC
1) Electrons are emitted by 25kV high voltage.
2) Electrons are pre-bunched by the buncher for matching the acceleration phase in the cavity.
3) Electrons are accelerated passing through linear acceleration cells.
4) Electrons are extracted through the exit hole.
*Electron energy is defined by the RF power.
*Lower energy electrons are also accelerated.
*Energy spread is more than 4%.

Features of MICROTRON in comparison with LINAC

① Beam current is higher than that of LINAC.
② Energy spread is smaller.
③ Compact and not heavy.
④ Power consumption is higher because acceleration efficiency is higher.
⑤ Single cell is easier to fabricate.
⑥ High voltage floating terminal is unnecessary thus the handling is safer.
⑦ Maintenance is easier. We only change filament once a year.
⑧ Shielding material is reduced.



MICROTRON



LINAC

滅菌･殺菌事業の展開

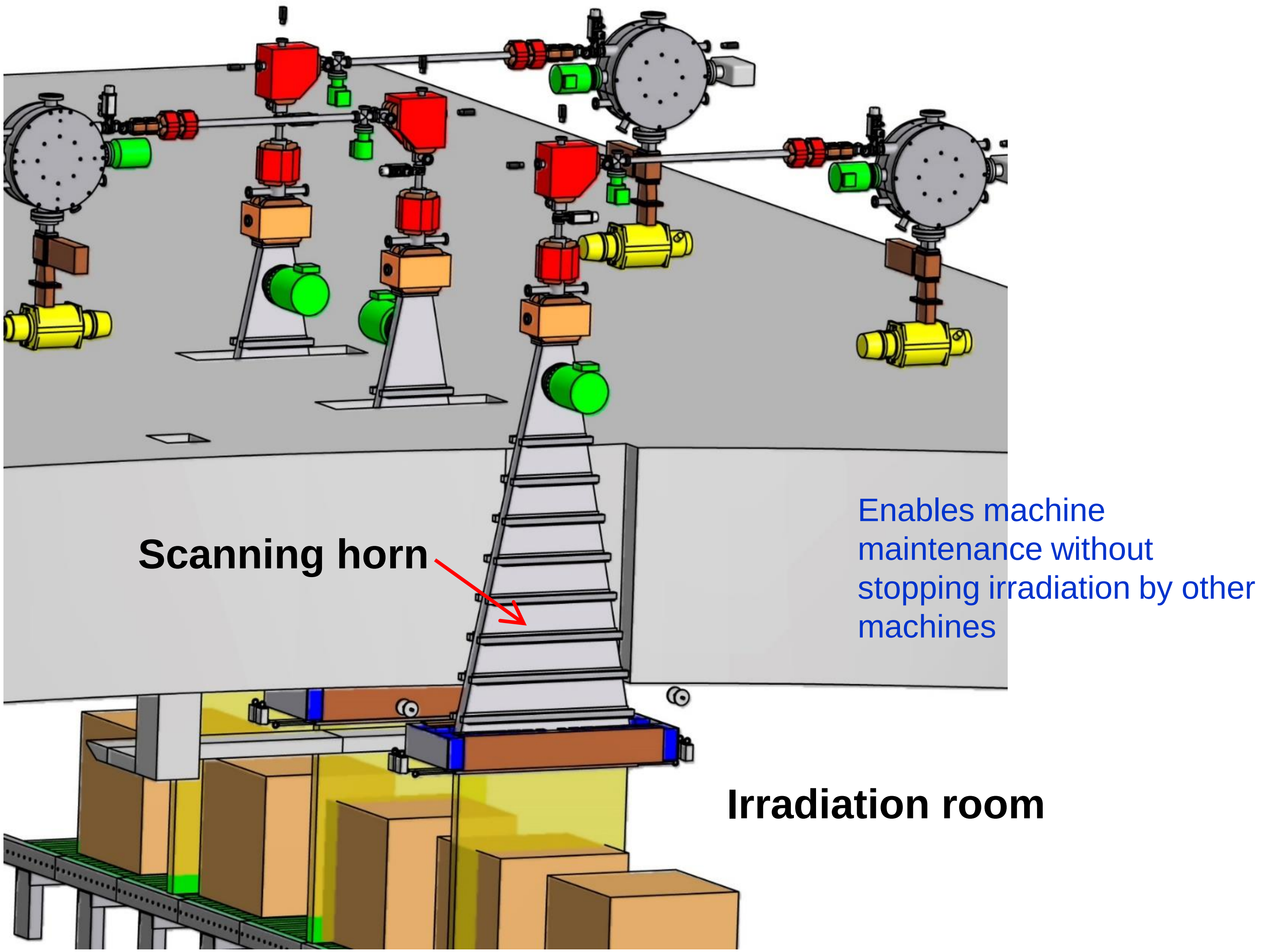
Photon Production Laboratory Co. Ltd.

30KW average by one machine is possible

since peak current is high!

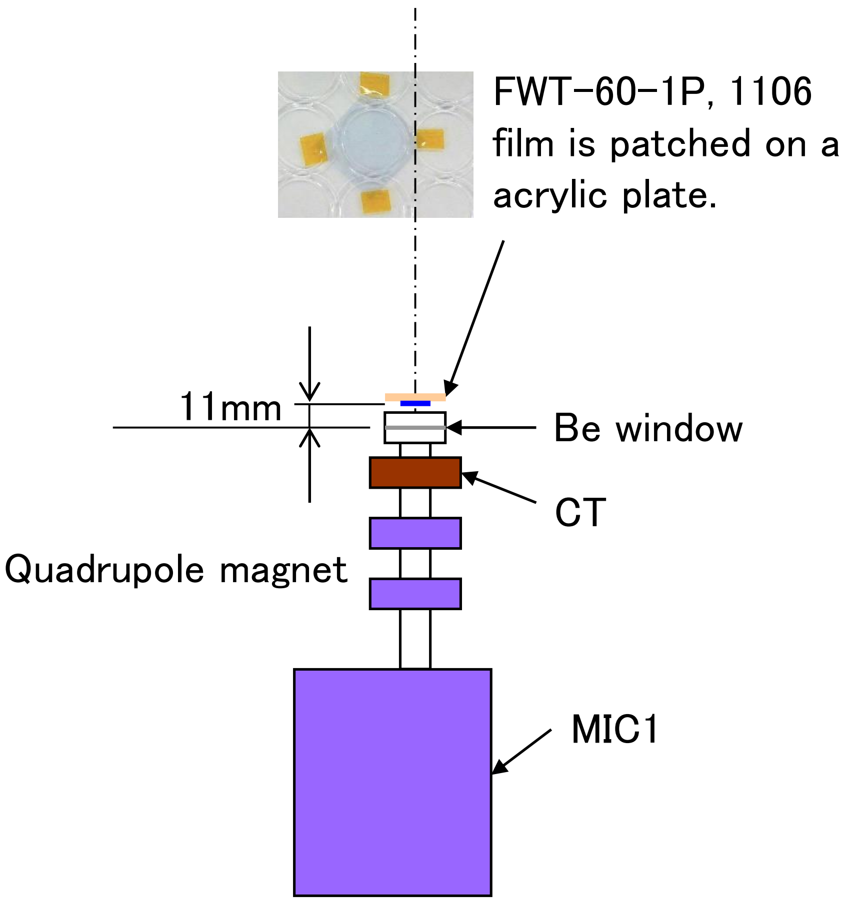
Model	2MeV high power type	10MeV high power type
Energy range [MV]	2	8.0 - 10.0
Pulse beam current [mA]	500	300
Pulse width [us]	5.0	5.0
Repitition rate [pps]	5,00	2,000
Average current [mA]	25	10
Beam output power [kW]	5	30
Klystron specification (model, frequency, average output power)	2,856MHz (50kW-ave)	2,856MHz (60kW-ave)
Weight (main body) [kg]	600	800
Body size	W40 x D15 cm	W40 x D60 cm
Cooling water flow [L/min]	350	400
Price (MUSD)	～3	～4

100, 200 KW irradiation is possible in tandem setup since it is compact

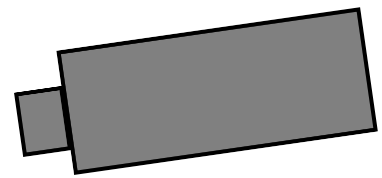


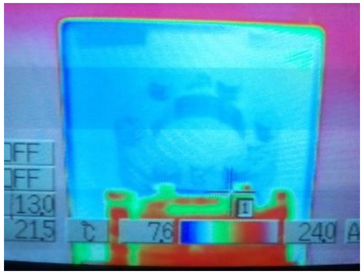
Irradiation test results by **MIC1**

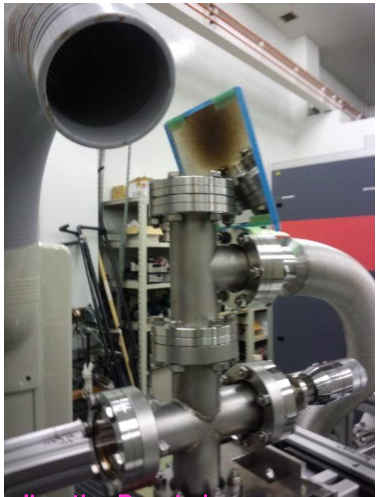
E-beam is extracted through 50 μm thick Be window		E-beam DOSE is monitored by the absorption rate in FWT-60-1P film (Batch 1106, 44.5um).	
Operation parameters	200mA, 30Hz, 200ns, 10s exposure	S-O distance	11mm



IR camera is used to monitor the temperature of window.

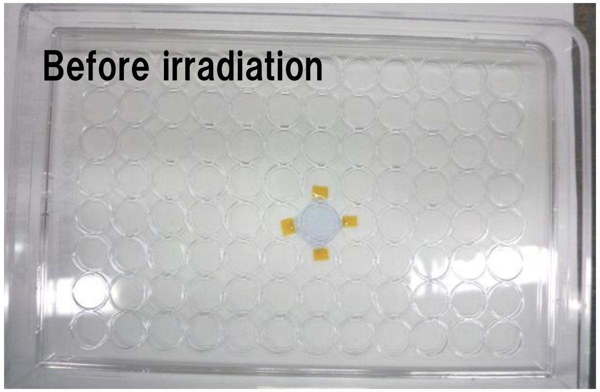






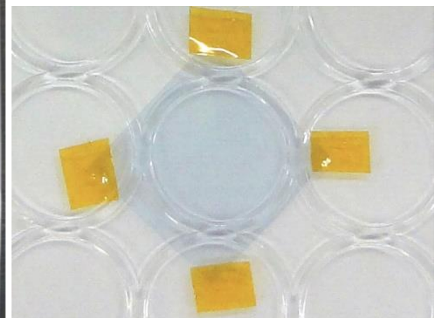
Cooling the Be window

Proof of e-beam dose of 1MeV machine at 200mA, 200ns, 30Hz, 10sec (12W) irradiation



At 605nm: 0.136
At 600nm: 0.135

FWT-60-1P, 1106 film



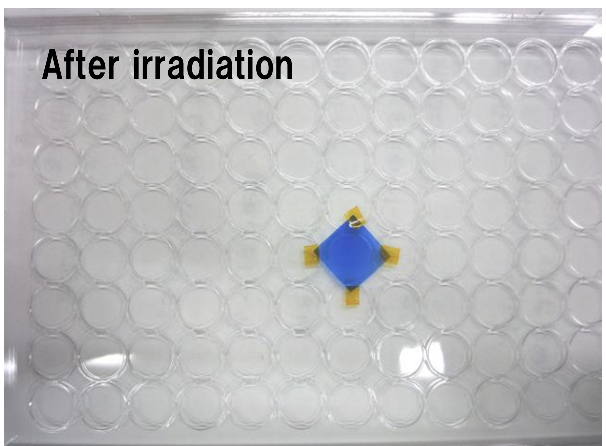
Before
605nm: 0.133
600nm: 0.133

After
605nm: 1.648
600nm: 1.616

k_{605} = (1.648 − 0.133) /0.0445
= <u>34.045</u>

k_{600} = (1.616 − 0.133) /0.0445
= <u>33.326</u>

Q_{605} = <u>25.27 kGy</u>

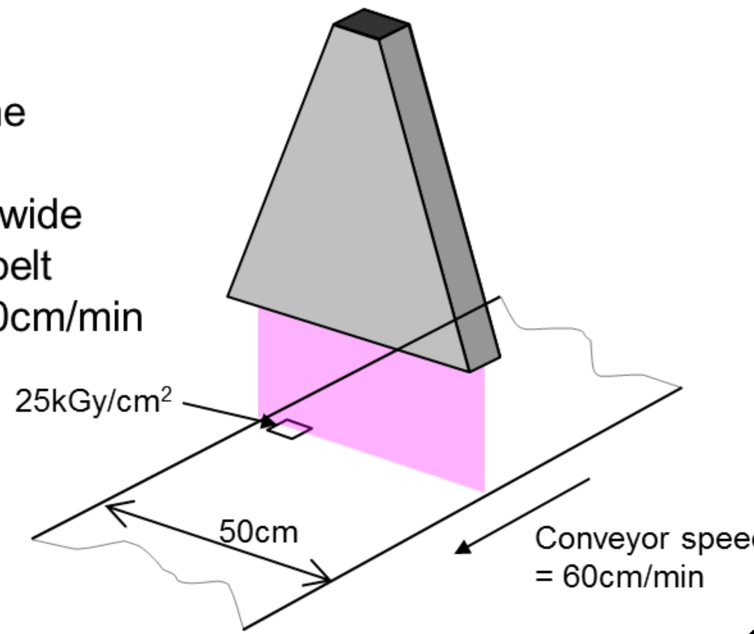


At 605nm: 1.305
At 600nm: 1.268

Co

Which enables

1kW 1MeV machine provides 25kGy/cm², 50cm wide irradiation field at belt conveyer speed 60cm/min



金属技研殿と提携しました