KRISS report to CCRI(I)

Chul-Young Yi
Korea Research Institute of Standards and Science (KRISS)

Primary standard development

1. KRISS air kerma primary standard

The air kerma standard of the KRISS for ^{60}Co and ^{137}Cs gamma-ray is a graphite-walled cavity ionization chamber designed and constructed by the KRISS, referenced as Y19-01. The density of the graphite wall is 1.836 g/cm^3 and the purity of the graphite is better than 5 μg/g. The insulator material of the graphite chamber is Kel-F (Polychlorotrifloroethylene, C_2ClF_3) with density of 2.142 g/cm^3. The cavity volume of the chamber is 1.6689 cm^3. The 3D image and simulation model of the primary standard chamber are shown in Fig. 1. The equi-potential distribution obtained by QuickField 5.6 is given in Fig. 2. The correction factors of the chamber for wall attenuation and scattering, radial and axial non-uniformity, re-absorption of bremsstrahlung, scattering from insulator compound were calculated by the Monte Carlo method using PENELOPE 2006.

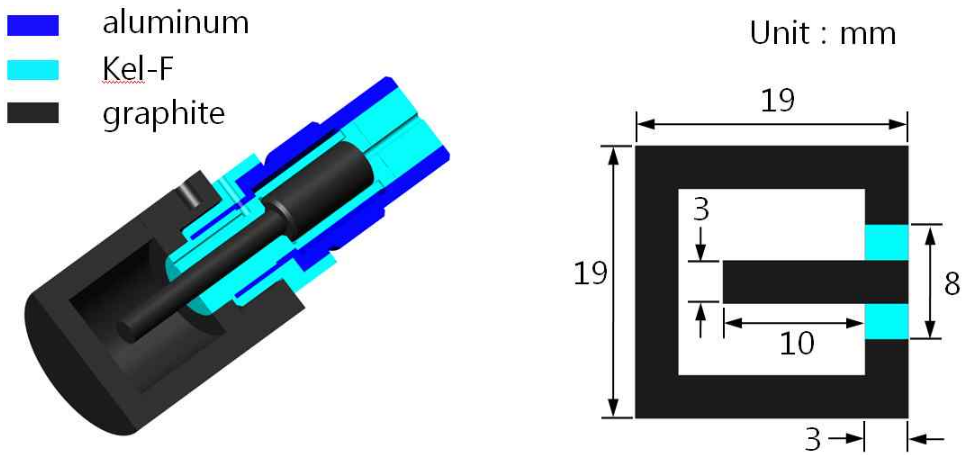


Fig. 1. KRISS primary standard graphite chamber Y19-01.
3D image (a) and simulation model (b).

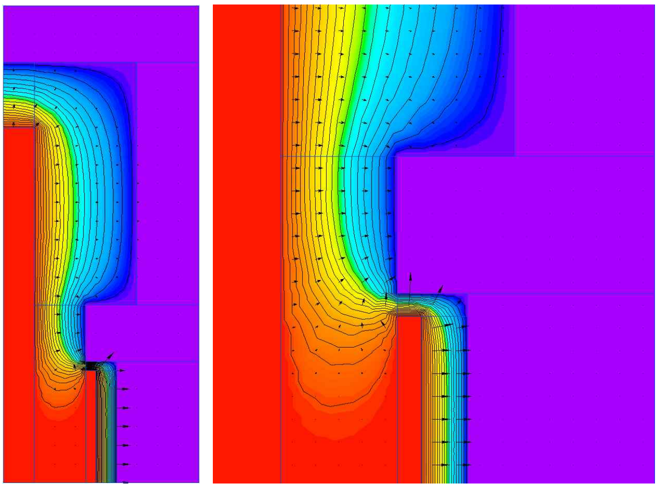


Fig. 2. Electric potential distribution around chamber neck of the KRISS standard.

Direct comparisons of the standards for air kerma of the Korea Research Institute of Standards and Science (KRISS), Korea, and of the Bureau International des Poids et Mesures (BIPM) was carried out in the ^{60}Co and ^{137}Cs radiation beam of the BIPM in 2010[1, 2].

2. Cs-137 gamma-ray irradiators

Three newly designed ^{137}Cs gamma-ray irradiators have recently been installed at KRISS, which is shown in Fig. 3. The nominal activities of the sources loaded to irradiators are 78.1 TBq, 4.8 TBq, 185 GBq, 37 GBq and 1.85 GBq. The granite-base precision stage was placed in front of the two irradiators of 78.1 TBq and 4.8 TBq sources where the ionization current was measured. The ionization chamber can be positioned in three degrees of freedom with a nominal resolution of 0.001 mm. The positioning accuracy was estimated to be within 0.02 mm. Three axes were orthogonal within 15 arc-seconds. The ionization chamber on the precision stage can move 0.9 m to 1.4 m in the beam direction. The 5 m-long rail systems were installed covering the distance range 2.5 m to 7.0 m from the 78.1 TBq and 4.8 TBq sources, and covering 1 m to 5 m for the other three sources, on which a multi-purpose trolley slides. The trolley movement can be controlled in resolution of 0.01 mm and the linear positioning repeatability was better than 0.1 mm.

The skeletal frame of the irradiator was made of thick stainless steel with inner void space surrounding the source holder in which melt lead was poured and filled. The lead-filled framework was then machined carefully and precisely. The sources were put in the source holder which were loaded to the irradiator in the KRISS hot-cell. The 78.1 TBq and 4.8 TBq sources are standstill in each of the two irradiators and irradiation is on and off using the cylindrical up-down shutters made of 90 mm diameter tungsten alloy.

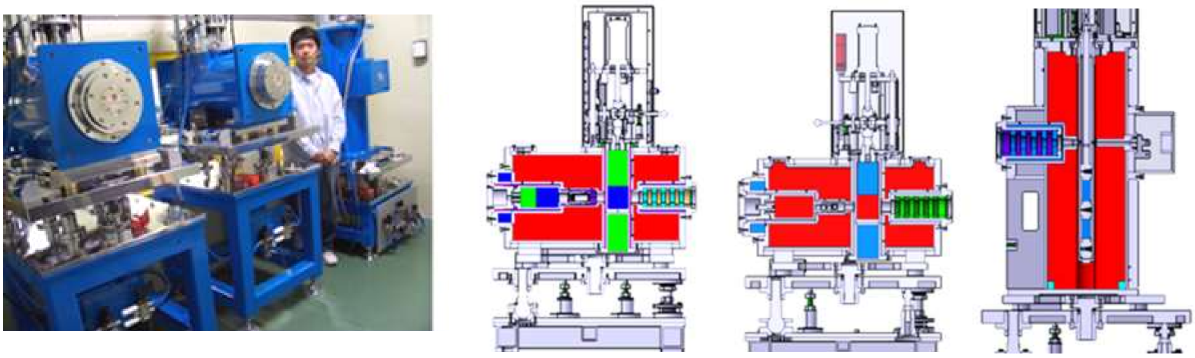
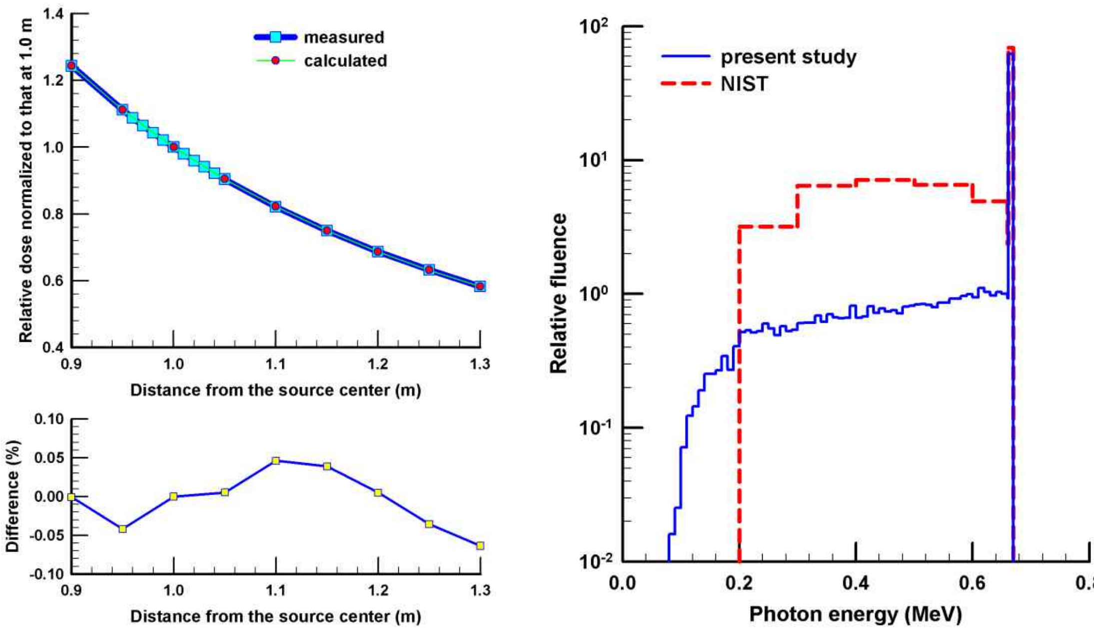


Fig. 3. Three KRISS ^{137}Cs gamma-ray irradiators and their design images.

The dimensions of the inner structures of the irradiators were measured carefully for the Monte Carlo calculation during machining or assembling stages of the irradiators. Monte Carlo calculations were carried out for the ^{137}Cs beam spectrum on the reference plane. The calculated air kerma as a function of distance are compared with experiment (Fig. 4(a)) and the agreement between the calculated and measured relative air kermas normalized at 1.0 m is satisfactory within 0.1% in the distance range 0.9 m to 1.3 m. The measured beam profile on the reference plane of the 78.1 Tbq ^{137}Cs beam is also presented in Fig. 4 (b).



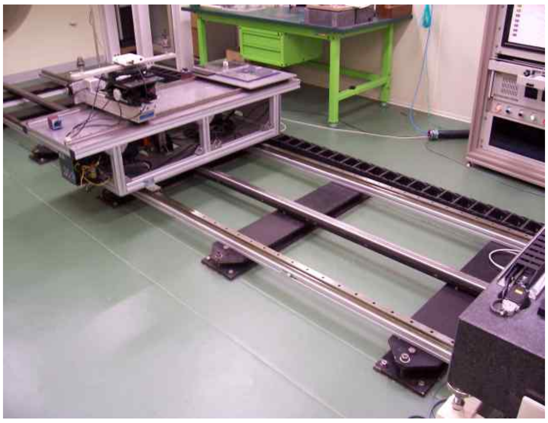
(a) **(b)**

Fig. 4. KRISS 78.1 TBq ^{137}Cs beam spectrum on the reference plane at 1 m from the source (a) and the relative air kerma as a function of distance (b).

3. Co-60 gamma-ray irradiator

The KRISS ^{60}Co gamma-ray irradiator is AECL model Eldorado 8, in front of which a granite base precision stage covering 0.9 m to 1.2 m from the source and the extension service rail covering up to 5 m from the source are followed (Fig. 5). The positioning accuracy of the precision stage was estimated to be within 0.02 mm. The activity of the ^{60}Co source is 145 TBq as of 21-06-2006. In the precision stage, the dosimeters and ionization chambers can be positioned with a resolution of 0.001 mm. A trolley sliding on the service rail moves with a resolution of 0.01 mm.

(a)



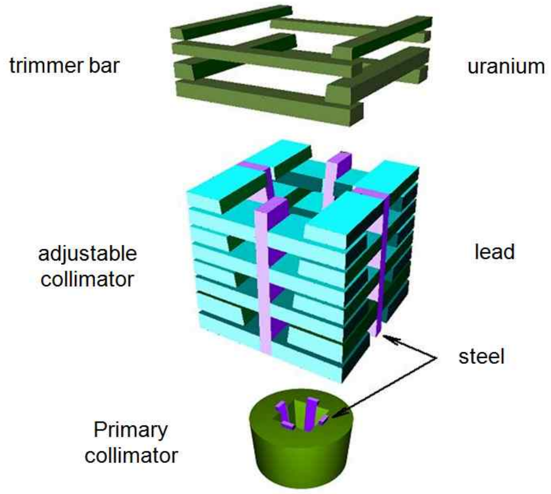
(b)

Fig. 5. KRISS ^{60}Co irradiator AECL model Eldorado 8 with a granite base precision stage placed in front of the irradiator (a) and extention service rail on which a trolley moves.

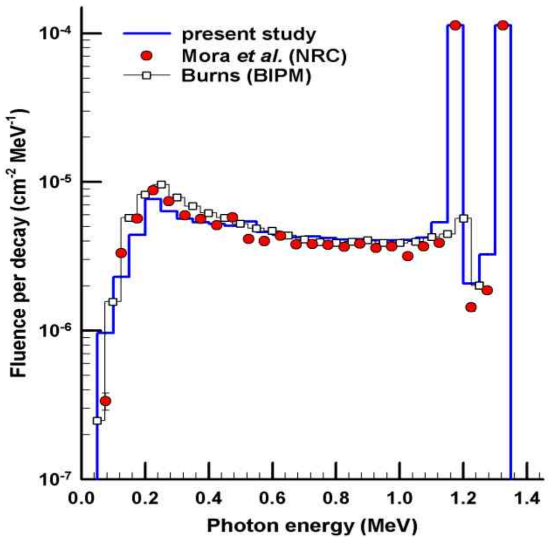
The ^{60}Co beam spectrum was calculated by means of the Monte Carlo method using PENELOPE 2006. The collimators were modeled realistically, and the material and dimensions of the ^{60}Co sealed source were extracted from the source certificate given by the manufacturer. The simulation model and the calculated ^{60}Co beam spectrum are shown in Figure 7. It was confirmed that the photon energy spectrum of KRISS ^{60}Co irradiation system was in similar shape with those of NRC and BIPM. In addition the ^{60}Co beam profile is given in Figure 6.

3. Low- and medium-energy X-ray irradiation system

Recently 320 kV X-ray irradiation system with X-ray tube Comet model MXR-320/26 has been installed at KRISS (Fig. 7). The X-ray system covers 10 kV to 320 kV X-rays. A granite base precision stage is located in front of the X-ray system. We have a cylindrical type FAC for the absolute measurement of low-energy X-ray air kerma. In addition two low-energy X-ray irradiation systems, one for 160 kV X-ray tube Comet model MXR-160/21 and the other for Mo/Rh-anode tube for the mammography X-ray standard are currently under manufacture.

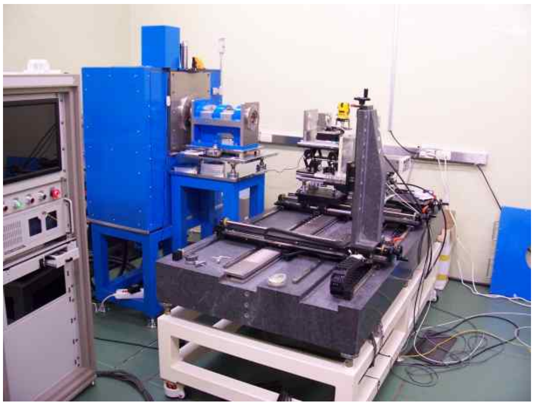


(a)

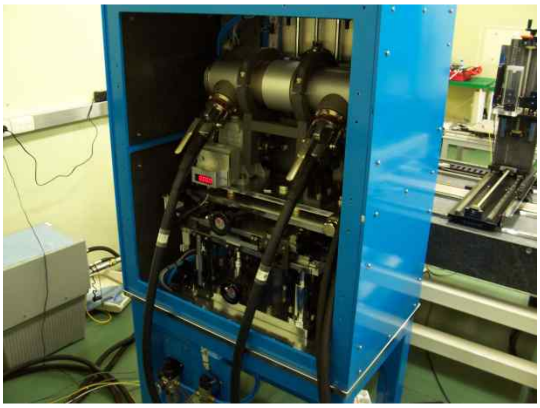


(b)

Figure 6. Simulation model of the KRISS ^{60}Co irradiator (a) and the calculated spectrum of the ^{60}Co beam on the reference plane at 1 m from the source.



(a)



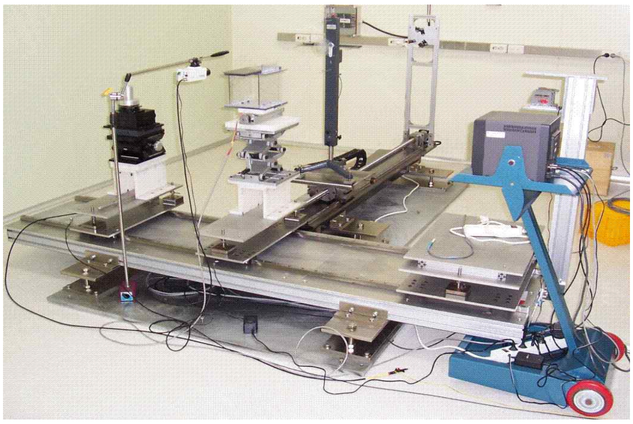
(b)

Fig. 7. KRISS 320 kV X-ray irradiation system with side view (a) and rear view (b).

4. Beta-ray absorbed dose to ICRU tissue

We have two beta-ray irradiation systems, one for the primary standard and the other for the secondary standard (Fig. 8). The primary standard beta-ray stand was set up on the granite base precision stage. The positioning accuracy of the extrapolation chamber in the precision stage was estimated to be within 0.03 mm. The Sr/Y-90 beta-ray field was prepared in compliance with ISO 6980. The absolute measurement of the absorbed dose to ICRU tissue was carried out using the PTW extrapolation chamber model 23392-082, the effective area of the electrode was determined by measuring the capacitance of the extrapolation chamber as a function of chamber depth (Fig. 9). An Andeen Hagerling ultra-precision capacitance bridge model 2500A with resonance frequency of 1 kHz was used for measuring the capacitance.

(a)



(b)

Fig. 8. KRISS beta-ray irradiation systems. The primary standard (a) and the secondary standard (b).

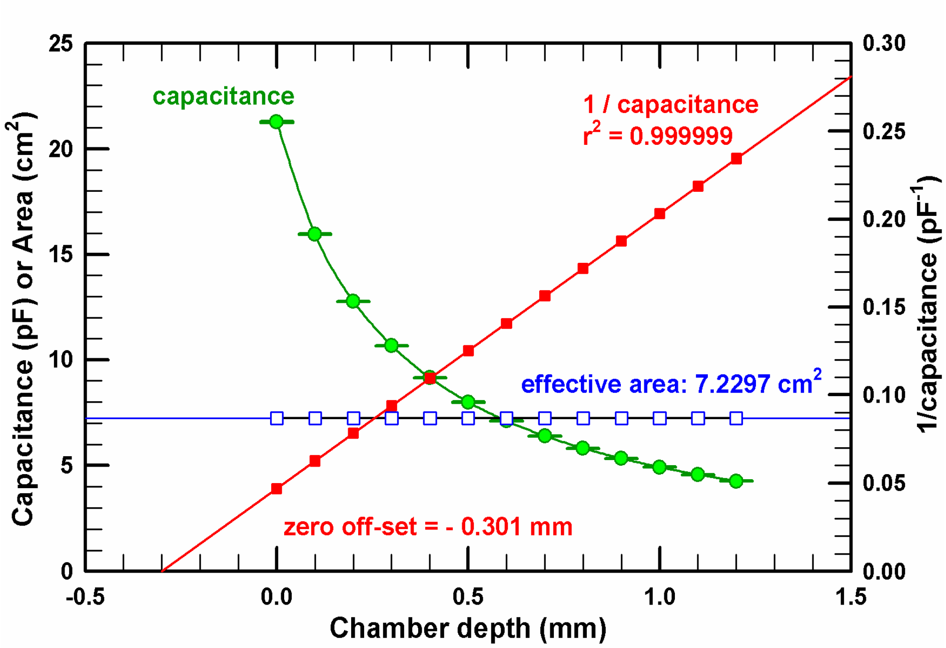


Fig. 9. Effective area of the electrode of the extrapolation chamber.

Beam profile of the Sr/Y-90 beta-ray on the reference plane at 300 mm from the source surface was calculated with PENELOPE 2006 and compared with experiment (Fig. 10). Agreements are satisfactory within a few tenths of a percent.

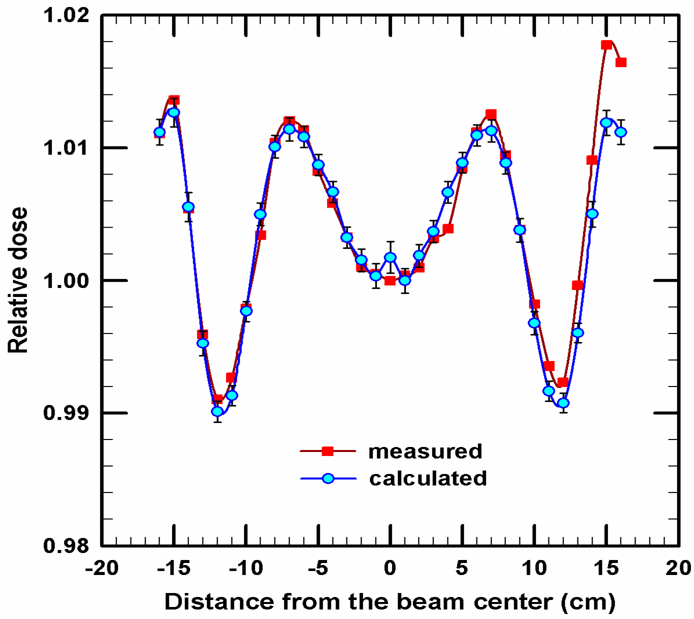


Fig. 10. Beam profile of the KRISS Sr/Y-90 beta-ray beam.

5. X- and gamma-ray spectroscopy and unfolding

A CdTe spectrometer was used for the measurements of low-energy X-ray spectra. In order to correct the spectral distortion due to the incomplete deposition of photon energy, we calculated the response matrix of the CdTe spectrometer and unfolded the measured spectra using the fortran subroutine Gravelw distributed by the OECD/NEA. The simulation model of the CdTe detector and the unfolded spectra are given in Figs. 11 and 12.

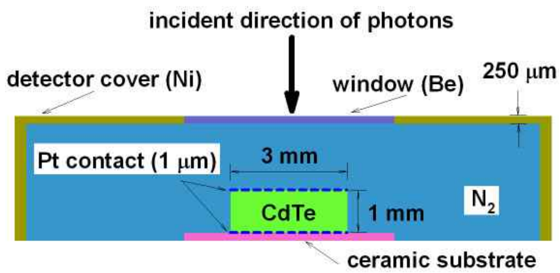


Fig. 11. Simulation model for the KRISS CdTe detector.

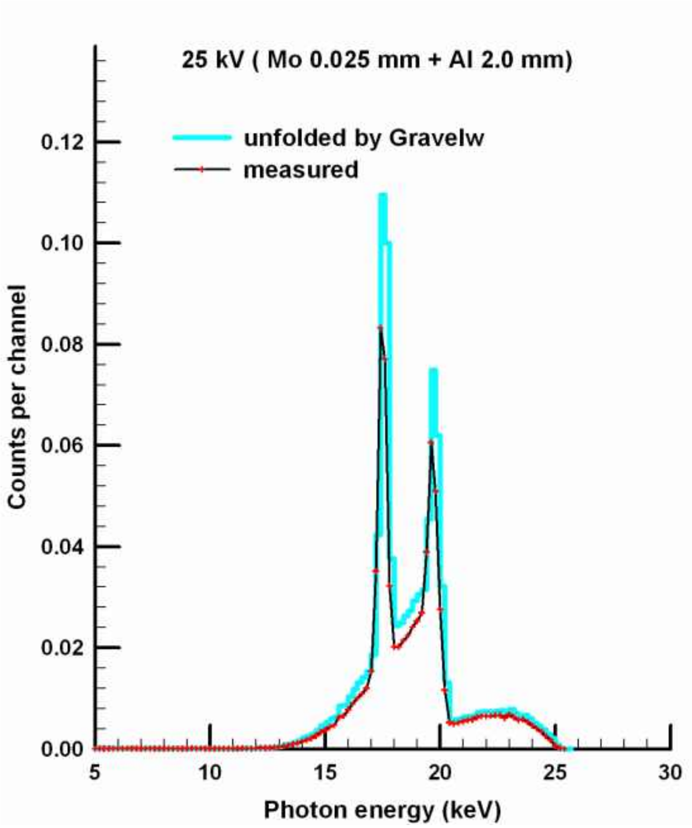
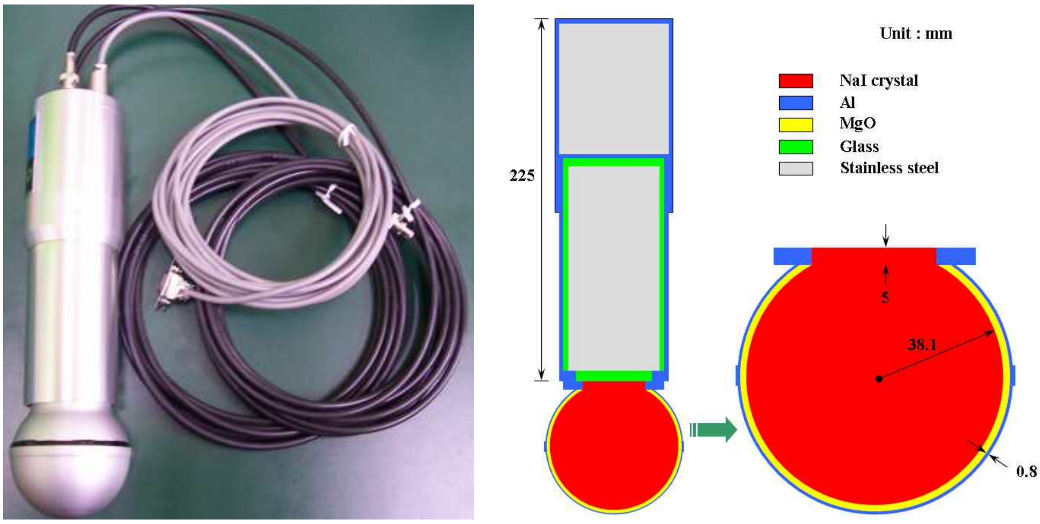


Fig. 12. Unfolding of the measured mammography X-ray spectrum by Gravelw.

Response characteristics of the 76.2 mm-diameter spherical NaI(Tl) detector were investigated by means of Monte Carlo method using PENELOPE 2006. Resolutions of the spherical detector were carefully measured for the precise calculation of the response functions. The scintillation yield given as a function of deposited energy was also considered. The simulation model is presented with the photo image of the spherical detector in Fig. 13 and the calculated spectra are compared with those measured in Fig. 14.

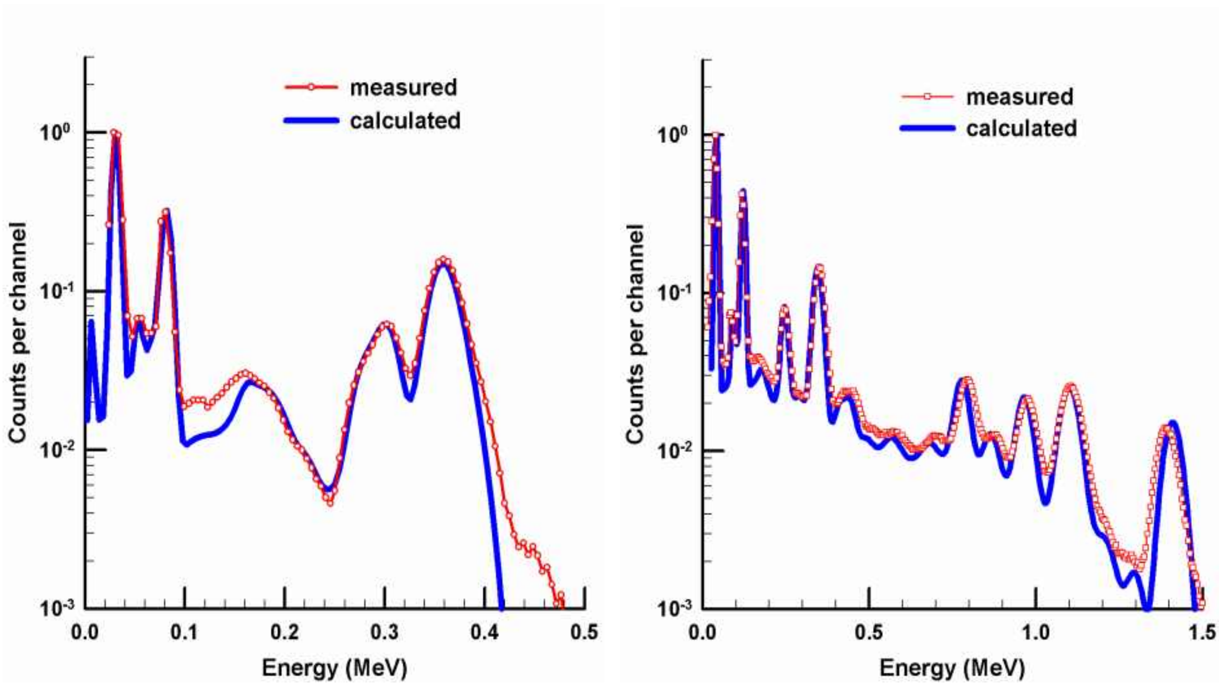
6. Dosimetry parameters of the Ir-192 HDR brachytherapy source

The Korea Atomic Energy Research Institute (KAERI) has developed a new HDR ^{192}Ir brachytherapy source model IRH10 (Fig. 15) which has been under pre-clinical tests. The HDR source IRH10 has a cylindrical active iridium core with diameter of 0.6 mm and length of 3.5 mm. The dosimetry parameters (Figures 16-18) of the IRH10 ^{192}Ir high dose rate brachytherapy source were obtained from the dose calculation formalism recommended in the AAPM Task Group No. 43 report using the Monte Carlo code PENELOPE 2006.



(a) **(b)**

Fig. 13. Photo image of the 76.2 mm-diameter spherical NaI(Tl) detector (a) and simulation model (b).



(a) **(b)**

Fig. 14. Comparison of the calculated spectra with those measured. Ba-133 gamma-ray spectrum (a) and Eu-152 gamma-ray spectrum (b).

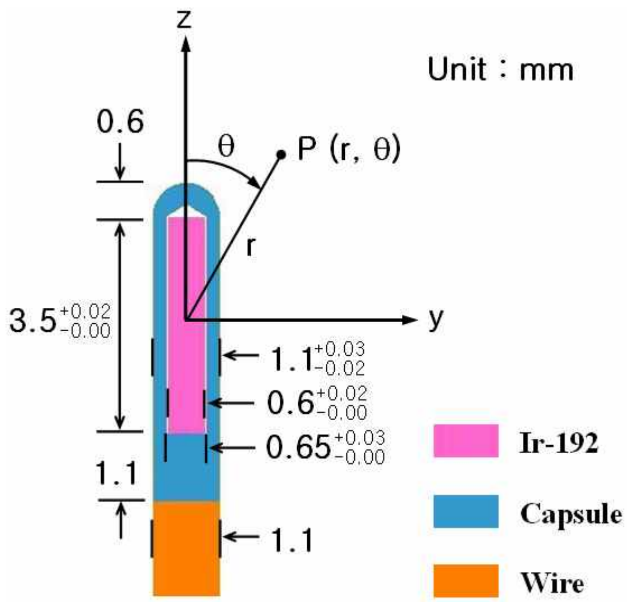


Fig. 15. HDR ^{192}Ir brachytherapy source IRH10. The coordinate system of the MC calculation is shown. The simulation model is the same as the original design.

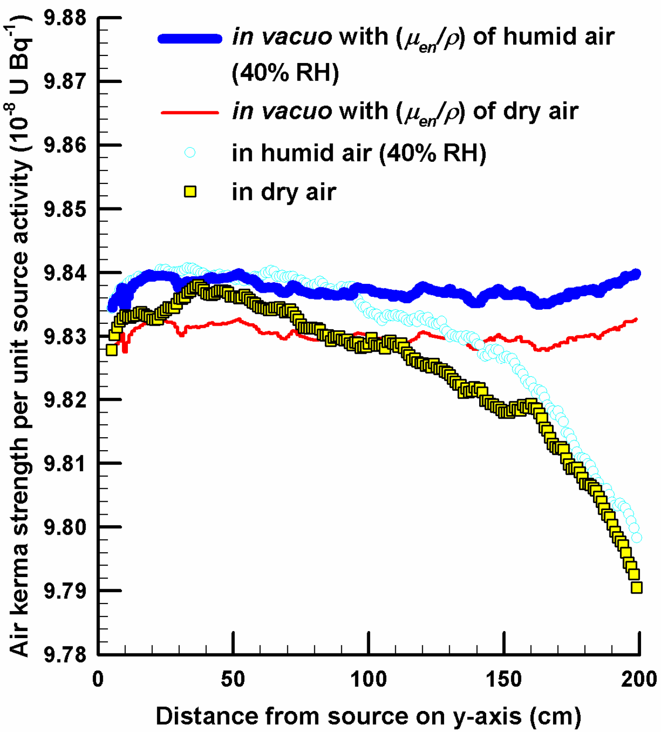


Fig. 16. The air kerma strength of IRH10 given as a function of the transversal distances.

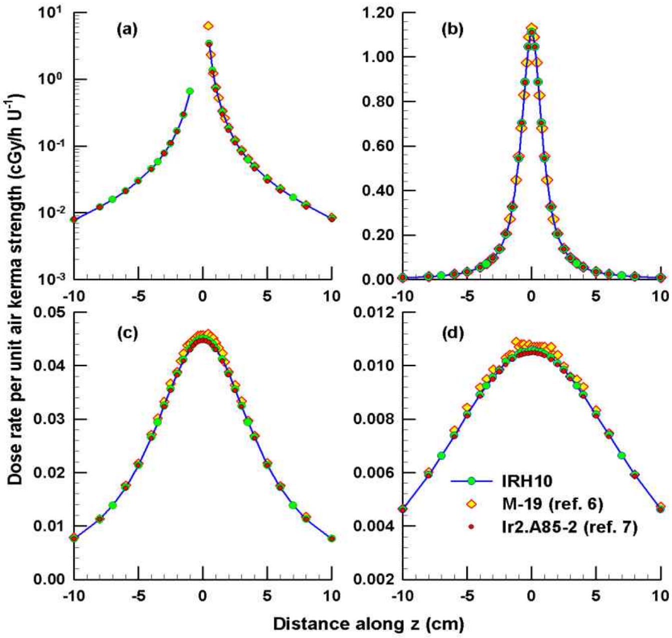


Fig. 17. The along-away data of IRH10 at various away distances. The data points in the figure are the dose rate per unit air kerma strength (cGy/h U^{-1}) at the transversal diatances of 0 cm (a), 1 cm (b), 5 cm (c) and 10 cm (d).

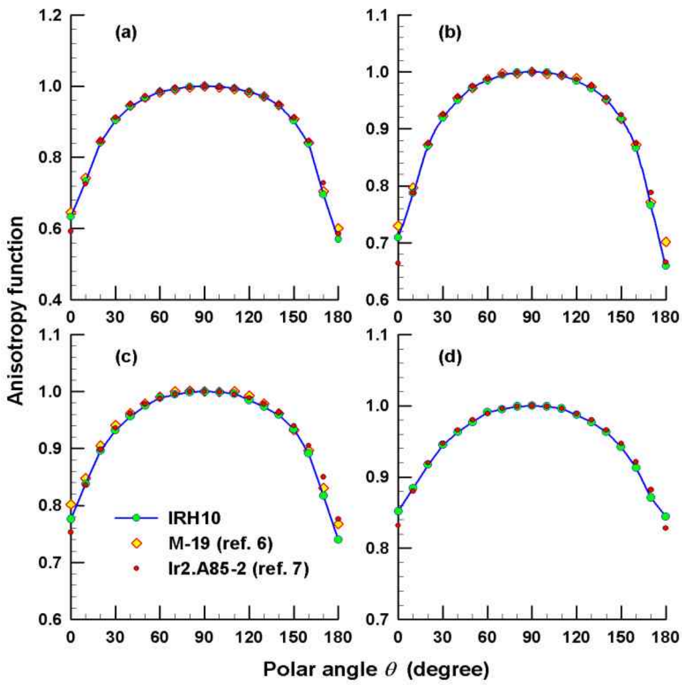


Fig. 18. The anisotropy function of IRH10 at the radial distances of 1 cm (a), 5 cm (b), 10 cm (c) and 20 cm (d).

7. Development of primary standard of water absorbed dose for LINAC

LINAC project has begun Jan. 1, 2011. LINAC building will be constructed during 2^{nd} half of 2011 and we expect LINAC will be installed by the end of 2011 when new building construction is completed. We are working on designing the graphite calorimeter to be used as a primary standard of water absorbed dose.

Quality management system

The Korea Research Institute of Standards and Science (KRISS) is the National Metrology Institute of the Republic of Korea and a signatory to the CIPM MRA. KRISS has chosen to self-declare the state of its quality system for calibration and measurement services without third-party accreditation. In order to establish the confidence and transparency required, certification to ISO 9001 has been obtained. This provides objective evidence that the management requirements of the quality system meet international quality standards. The technical competence of the laboratory and its personnel to undertake the specific calibration and testing has been reviewed in a period of 5 years against the technical requirement of ISO/IEC 17025 through the peer review process. The revised CMC table has recently been submitted to APMP with an answer sheet to comments from other RMOs in April, this year.

Dissemination of standards

There are 8 secondary standard dosimetry laboratories in Korea, which have been accredited from the Korea Laboratory Accreditation System (KOLAS). Our mission is to provide the national standards to those secondary standard laboratories. There are 24 commercially operating nuclear power plants and 4 others are under construction. We have around 200,000 radiation workers in Korea. Sometimes we carry out calibration services to users directly when requested. Tests and measurement services have been provided to users & governmental bodies on request.

Research staff

3 research scientists and 1 technician. We have been recruiting one research scientist.

Publication (2009 – 2010)

1. C. Kessler, Chul-Young Yi, Jae-Pil Chung, P. Roger, P. J. Allisy-Roberts, "Comparison of the standards for air kerma of the KRISS and the BIPM for ^{60}Co gamma radiation," Metrologia 47 (2010) 06021.
2. C Kessler, P Roger, P J Allisy-Roberts and Chul-Young Yi, "Comparison of the standards for air kerma of the KRISS and the BIPM for ^{137}Cs gamma radiation," Metrologia 47 (2010) 06022.
3. Chul-Young Yi, Kook Jin Chun, Suck-Ho Hah, Hyun-Moon Kim and Chunil Lim, "Dosimetry parameters of the IRH10 ^{192}Ir high dose rate brachytherapy source", J. Radiat. Res. 51 (2010) 485-492.
4. Chul-Young Yi and Wan-Seop Kim, "Large excessive current during the calibration of electrometer by use of a capacitive low-current source", 2010 Conference on Precision Electromagnetic Measurements, June 13-18, Daejeon Korea (2010) 595-596.
5. Chul-Young Yi, Kook Jin Chun, Suck-Ho Hah, Hyun-Moon Kim and Chunil Lim, "Dosimetry parameters of the IRH10 ^{192}Ir high dose rate brachytherapy source", J. Radiat. Res. 51 (2010) 485-492.
6. Chul-Young Yi and Wan-Seop Kim, "Large excessive current during the calibration of electrometer by use of a capacitive low-current source", 2010 Conference on Precision Electromagnetic Measurements, June 13-18, Daejeon Korea (2010) 595-596.
7. Chul-Young Yi, Kook Jin Chun, Suck-Ho Hah, Hyun-Moon Kim and Chunil Lim, "Dosimetry parameters of the IRH10 ^{192}Ir high dose rate brachytherapy source", J. Radiat. Res. 51 (2010) 485-492.
8. Chul-Young Yi, Suck-Ho Hah, Kook Jin Chun and Hyun-Moon Kim, "Monte Carlo Calculation of the Spencer-Attix graphite-to-air stopping power ratios for photon beams", J. Kor. Phys. Soc. 56(3) (2010) 926-929.
9. Kook Jin Chun, Youngho Park, Yongsoo Choi and Sangil Hyun, "A numerical approach to dose optimization for moving targets using Monte Carlo simulations", Radiat. Res. 171 (2009) 245-253.