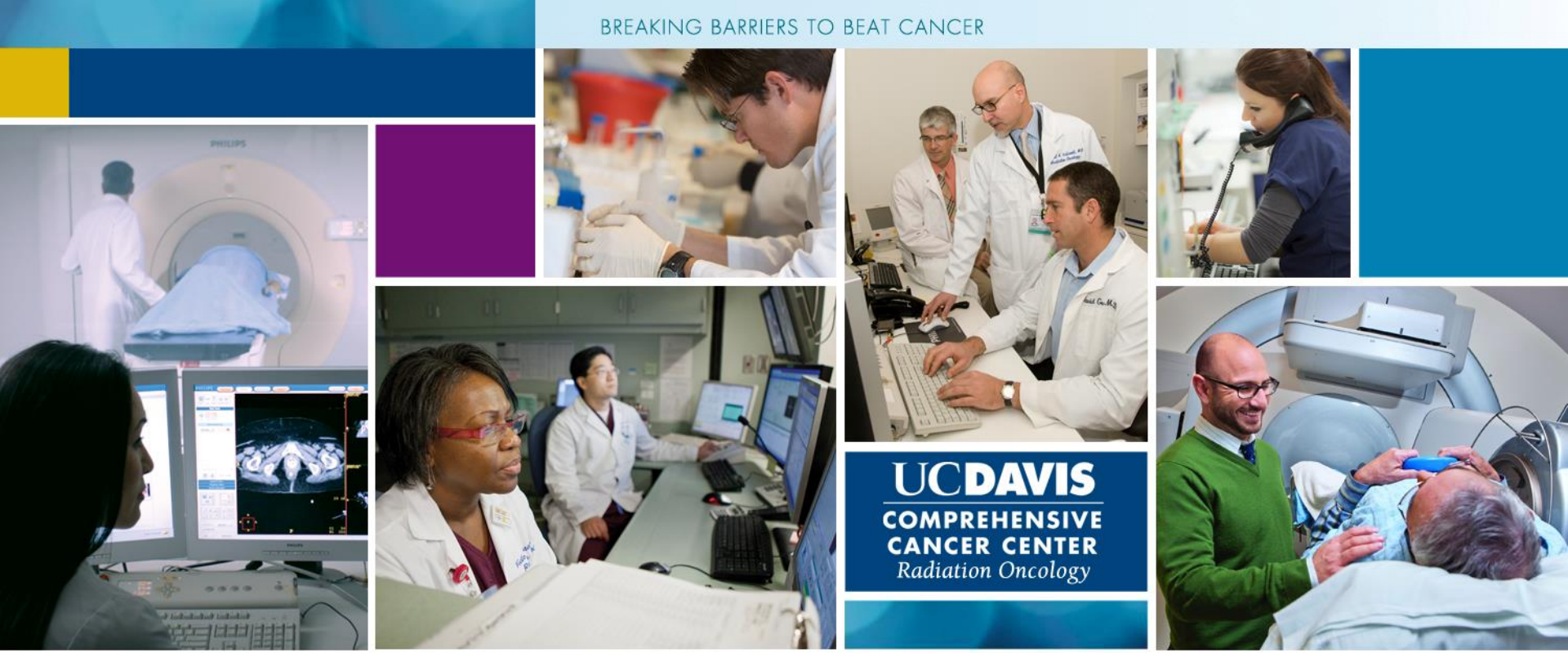
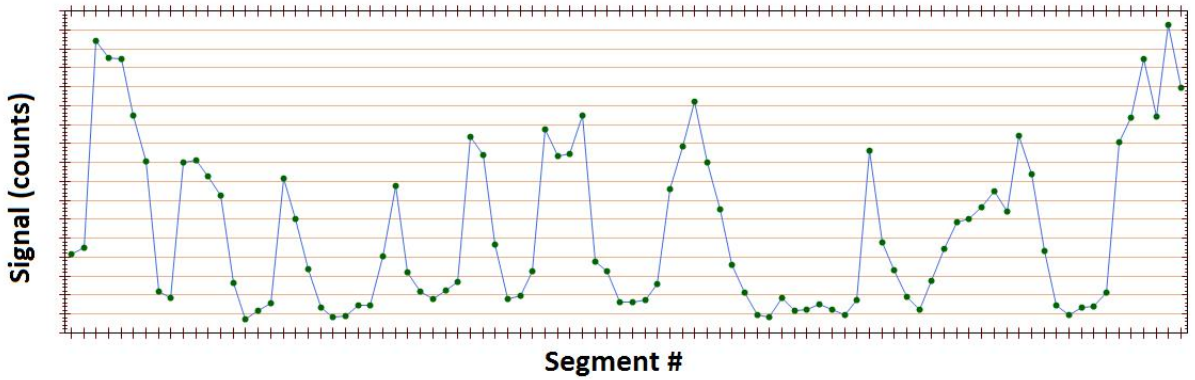


Online quality assurance of external beam radiation therapy with an integrated quality monitoring system

David Hoffman, Ph.D.
University of California, Davis
Resident Physicist
July, 2015

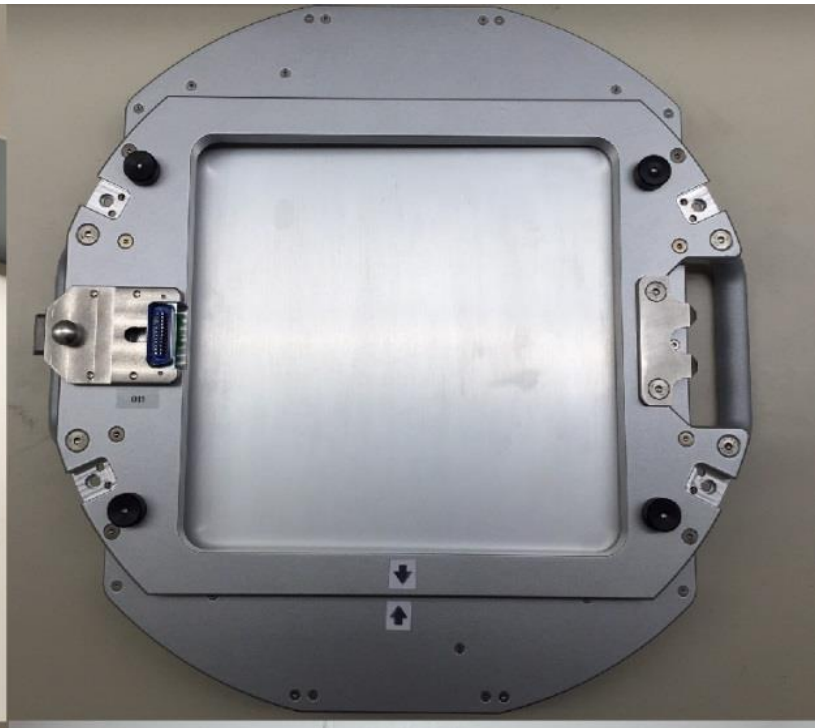
Integral Quality Monitor (IQM)

- Large area ion chamber
- iRT Systems GmbH (Koblenz, Germany)
- Attaches to the accessory tray
- Online checksum QA for photon beams



Overview

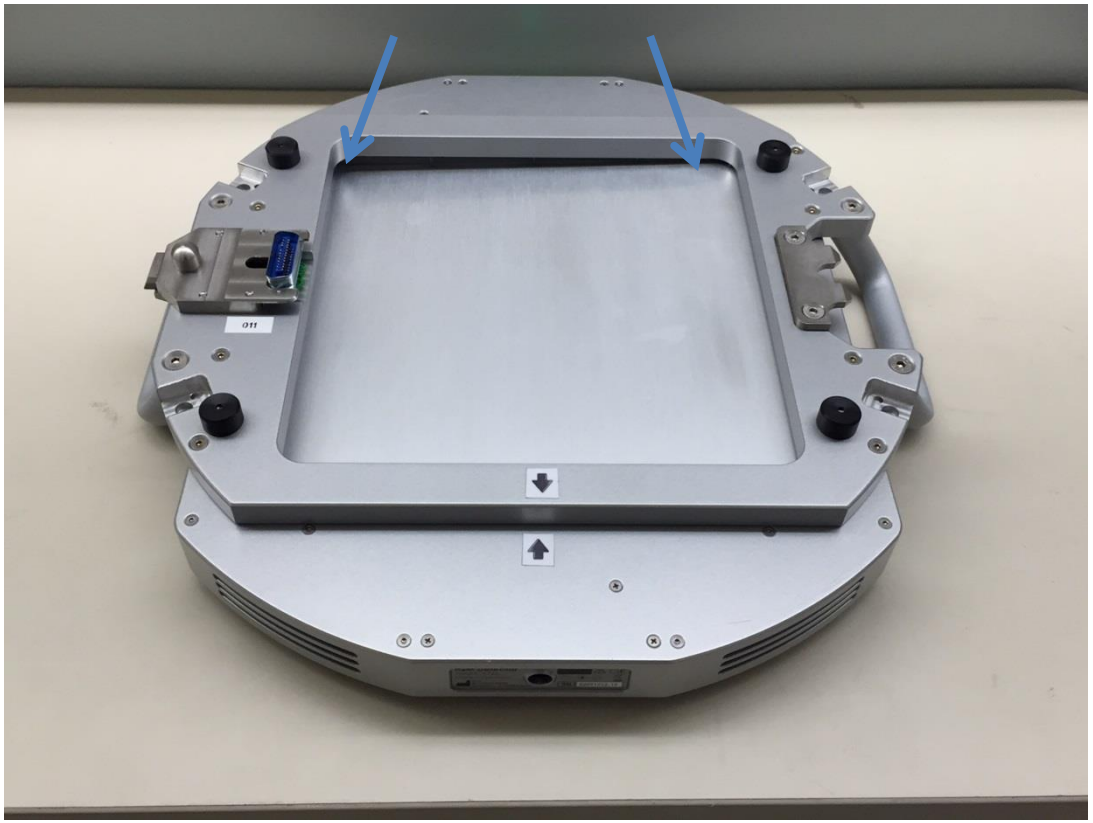
- Evaluate the stability and accuracy of each feature of the IQM.
- Determine much medical physics work is needed to bring the IQM into a clinic.
- Quantify how sensitive is the device to beam delivery errors.



Chamber Characteristics

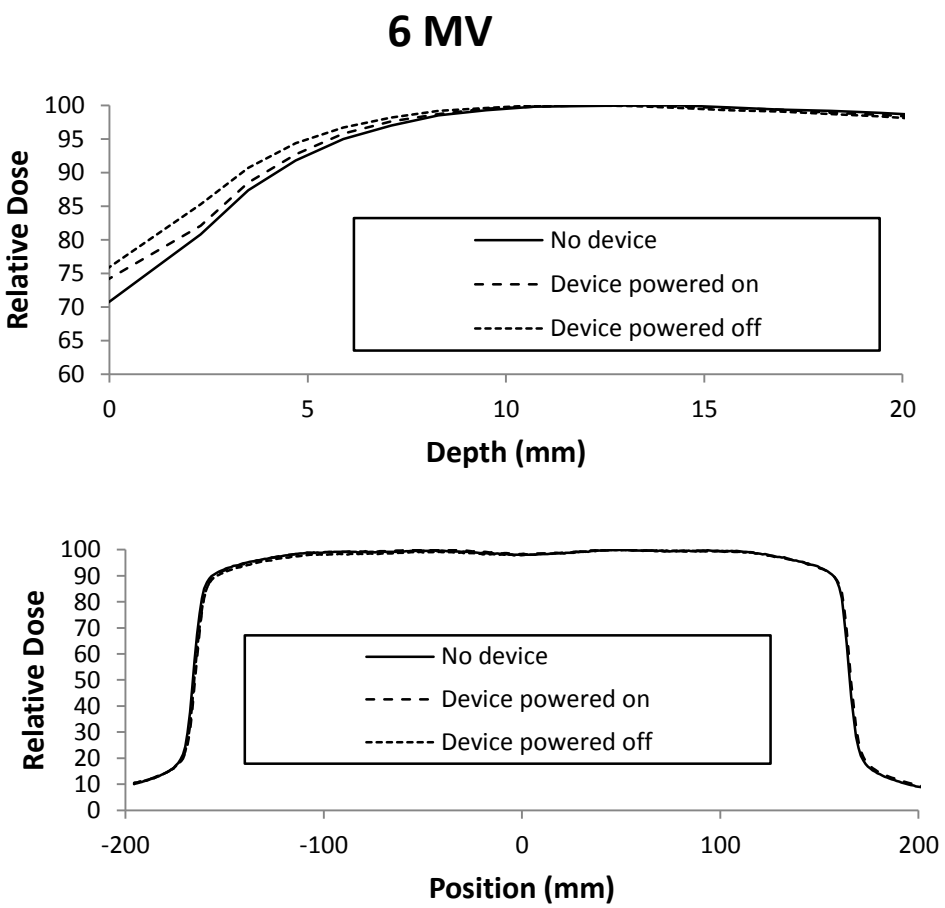
- Ion chamber thickness gradient in the axis of MLC motion
- Inclinometer for gantry and collimator angle measurement
- Wireless connection

Ion chamber gradient



Effect on Photon Beams

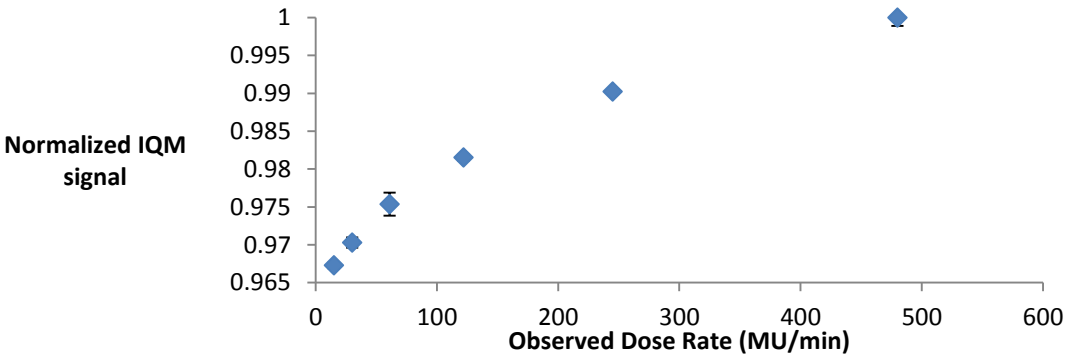
- Attenuation of photon beams:
  - 6 MV - 5.43 ± 0.02%
  - 10 MV - 4.60 ± 0.02%
  - 15 MV - 4.21 ± 0.03%
- Symmetry and flatness is unchanged
- Beam profiles agree with within 1% outside of the penumbra
- Presence of the IQM can be accounted for with a tray factor



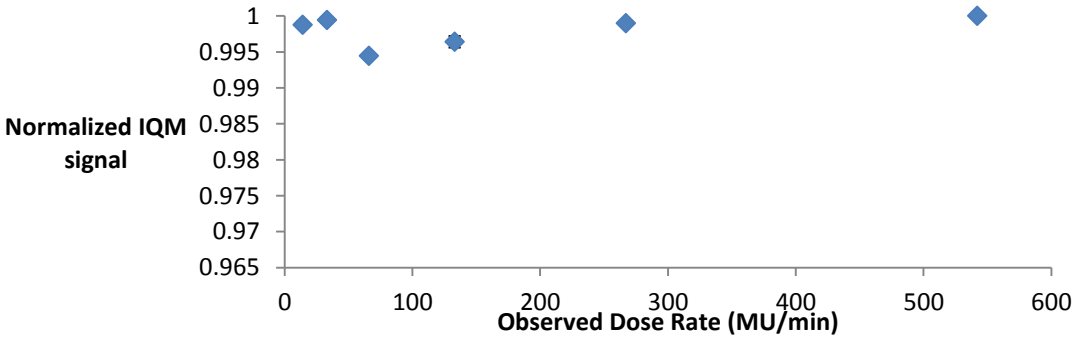
Ion chamber evaluation

- Simple photon beam measurements
  - Reproducibility (SD = 0.14%)
  - Stability over 4 weeks (SD = 0.47%)
- Linear dependence on MU (R^2 = 1)
- Initial dose rate dependence (3-4%)
- Faster capacitor resulted in minimal dependence

Original PCB



Redesigned PCB



Further evaluation

- IQM thermometer agreed to the calibrated thermometer to within 1.0 ± 0.7°C
- IQM barometer agreed to the mercury barometer to within 2.3 ± 0.4 mmHg
- IQM inclinometer agreed with the spirit level for gantry:
  - 0 and 180 degrees within 0.03 ± 0.01 degrees
  - 90 and 270 degrees within 0.27 ± 0.03 degrees
- For the collimator angle measurement, the IQM inclinometer agreed with the plum-bob within 0.3 ± 0.2 degrees with the gantry at 90 degrees.
- No Collimator angle readout when the gantry is within ~5 degrees of 0 or 180 degrees

Simulated errors

- Modifications to the photon beams results in changed ion chamber response
- Simulated errors were detected in 6 MV 10×10 cm^2 photon beam
- Twice the SD of the stability (1%) of the measurement was considered a "detected" error

Modification	% signal change	Magnitude of modification for 1% change
1% decreased MU	-0.99± 0.01%	-
1% increased MU	1.00 ± 0.03%	-
1 mm single MLC leaf into field	-0.05 ± 0.01%	13 mm
1 mm single MLC leaf out of field	0.01 ± 0.01%	25 mm
1 mm field shift in MLC motion axis	0.42 ± 0.06%	3 mm
1 mm field shift in MLC non-motion axis	0.20 ± 0.13%	Not sensitive
Incorrect energy (10 MV)	0.8 ± 0.02%	-
Incorrect energy (15 MV)	2.85 ± 0.01%	-

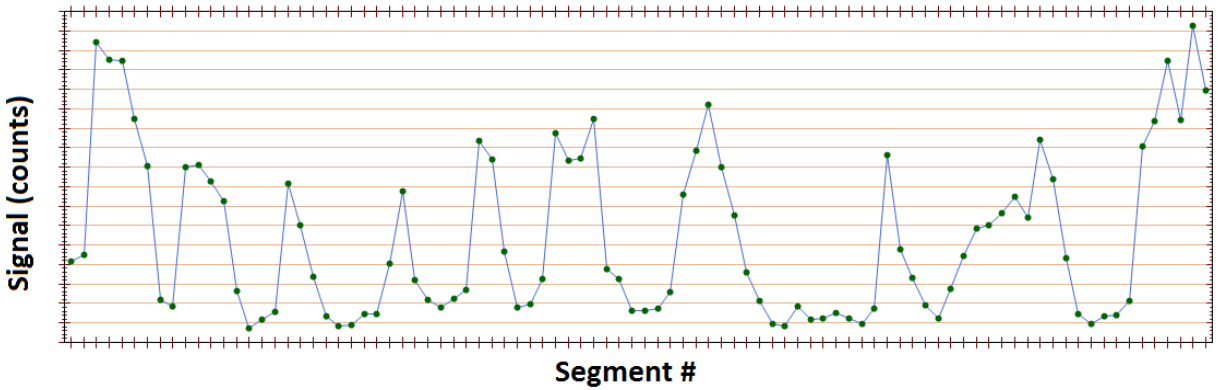
Small fields

- The IQM does not have a finite detector size
- For small fields (SBRT), this changes the detectable errors
- Simulated errors were detected in 6 MV 1×1 cm^2 photon beam

Modification	% signal change	Magnitude of modification for 1% change
1% decreased MU	-1.1± 0.4%	-
1% increased MU	1.02 ± 0.3%	-
1 mm single MLC leaf into field	-0.7 ± 0.2%	1.5 mm
1 mm single MLC leaf out of field	0.5 ± 0.3%	1.5 mm
1 mm field shift in MLC motion axis	0.1 ± 0.3%	4 mm
1 mm field shift in MLC non-motion axis	0.6 ± 0.4%	Not sensitive
Incorrect energy (10 MV)	8.5 ± 0.3%	-
Incorrect energy (15 MV)	15.1 ± 0.3%	-

VMAT evaluation

- Two VMAT prostate plans were repeatedly measured
- IQM ion chamber measurement SD = 0.16%



Ongoing investigation

- IQM measurement in further applications:
  - Conventional 3D
  - IMRT
  - VMAT
  - SBRT
  - High dose rate
- Evaluation of treatment error detection sensitivity

Conclusions

- The IQM demonstrated:
  - Valid temperature and pressure correction
  - Useful gantry and collimator angle readings
  - Valid and reproducible photon beam measurements
  - Sensitivity to simulated beam delivery errors
- Useful for online patient quality assurance
- Implementation does not require re-commissioning of the treatment beams