



Quality Assurance Program of Biological X-ray Irradiators: Measurement of the Beam Quality Index (BQI)



Chu Wang^{1,2}, Terry Yoshizumi^{2,3}

1 Medical Physics Graduate Program, Duke University Medical Center, Durham, NC 27705

2 Duke Radiation Dosimetry Laboratory, Duke University Medical Center, Durham NC 27710

3 Department of Radiology, Duke University Medical Center, Durham, NC 27710

Introduction

A good quality assurance (QA) program for biological irradiators is essential for accurate radiation dosimetry for radiobiological research. For x-ray irradiators, the peak voltage (or kVp) is one of the most fundamental system parameters; however, at levels higher than 160 kVp, the kVp is difficult to measure with conventional x-ray QA instruments. The purpose of this study is to establish the *Beam Quality Index (BQI)*, a quantity strongly correlated to the kVp, as an alternative parameter for kVp validation as a part of the QA program for biological x-ray irradiators.

Materials and Methods

In this study, we measured the Beam Quality Index (BQI), a quantity strongly correlated to the kVp, for three biological x-ray irradiators, (Model: X-Rad 320; Precision X-ray Inc. (PXI), North Branford, CT), using a multi-purpose QA meter (Meter Model: Piranha; Data Acquisition Software on PC: Ocean Professional; Mölndal, Sweden). Of the three irradiators, Irradiator #1, located at the PXI assembling facility, was energy-calibrated with a voltmeter and the irradiator's built-in high-voltage divider in the circuitry, thus serving as our gold standard, and Irradiators #2 and #3 are located at Duke University.

BQI measurements on Irradiators #1 and #2 were performed from 80 to 320 kVp, in 20 kVp intervals, with four filtration levels:

- No filter
- F1 (2 mm Al)
- F2 (0.8mm Tin + 0.25mm Cu + 1.5mm Al)
- F4 (0.1mm Cu + 2.5 mm Al)

BQI measurements on Irradiator #3 were performed from 100 to 320 kVp, in 20 kVp intervals, with only the F1 filter.

For each irradiation session, the BQI was tracked for the first 8 seconds, with 250 samples per second.

Results & Discussion

BQI time-plots (sample plots shown in Figure 1) demonstrate the BQI, and hence the kVp, ramp-up at the beginning of exposure, plateau-region during exposure, and the sharp drop-off at the end of exposure.

Different ramp-up times were due to the different settings in the power supply units of the irradiators.

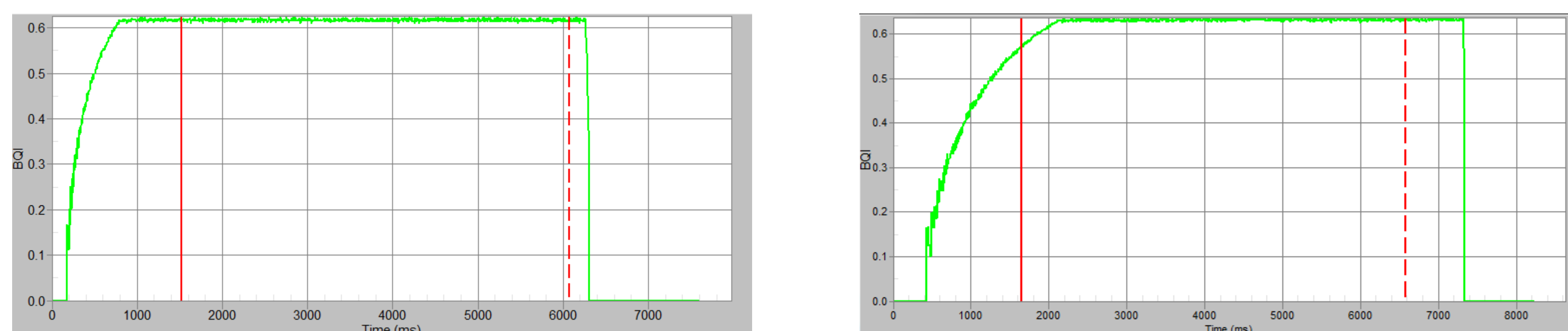


Figure 1 Sample BQI time-plots (Left: Irradiator #1, F1 Filter, 320 kVp; Right: Irradiator #2, F1 Filter, 320 kVp)

BQI measurements are shown in Figure 2 below. At each filtration level, a fourth-order polynomial is used to fit the BQI data points of Irradiator #1.

Good agreements (<5%) were observed between Irradiator #1, the gold standard, and Irradiators #2 and #3. Across different filtrations levels, the BQI values for No Filter, F1 Filter and F4 Filter were within 10% each other at each kVp level; the much higher BQI values for F2 Filter were most likely the result of significantly hardened beam spectra.

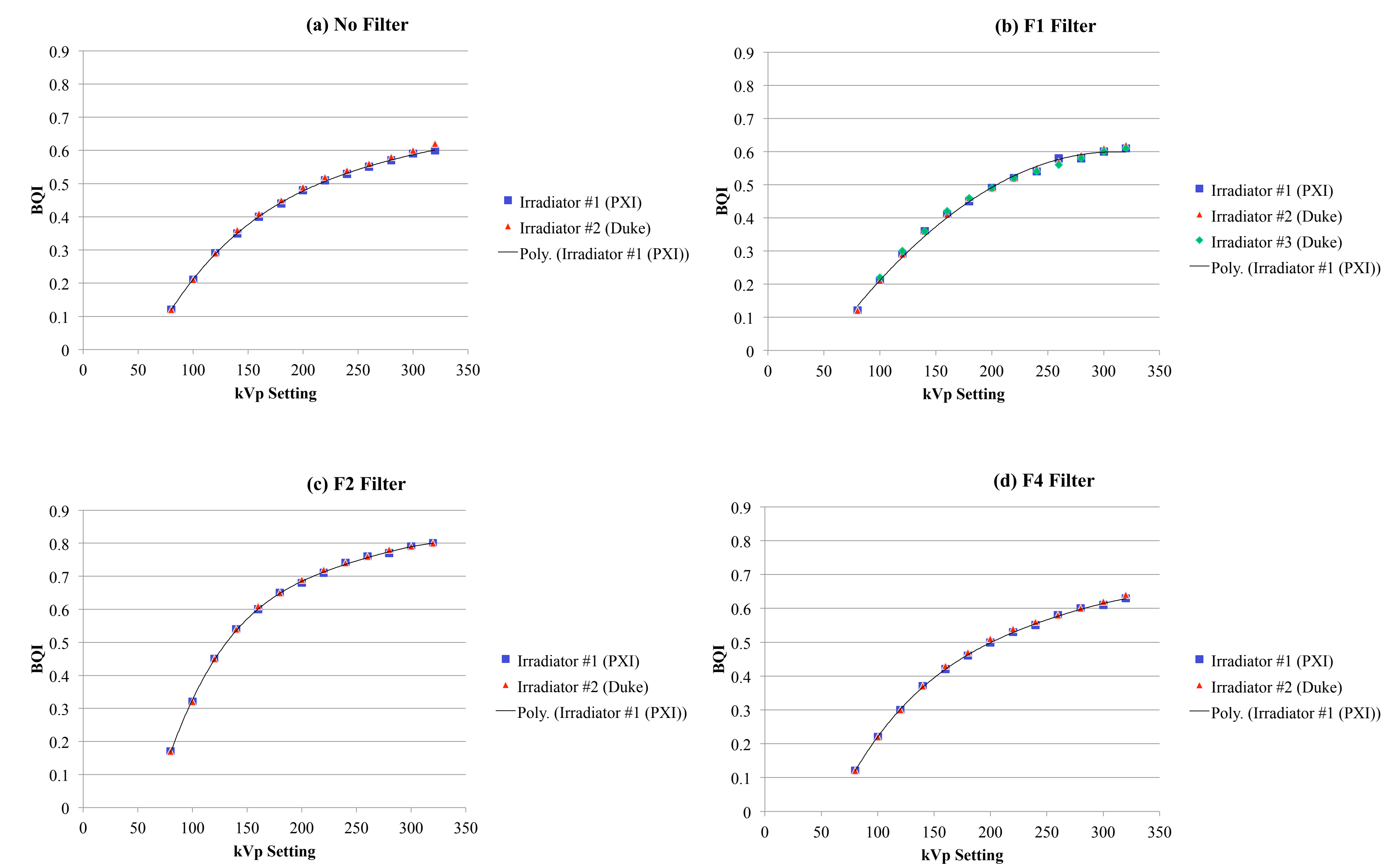


Figure 2 Measured BQI at the three X-Rad 320 Irradiators at various filtration levels (a) No Filter; (b) F1 Filter; (c) F2 Filter; and (d) F4 Filter.

Conclusions

In the absence of any direct kVp verification capability, the BQI serves as an alternative quantity for x-ray beam energy calibration. Spectrum-specificity has been observed with different filtrations, more significant with the F2 filter. Therefore, as part of an irradiator QA program, the energy calibration can be done by measuring the BQI and comparing it to a reference BQI-kVp calibration curve for the x-ray spectrum of interest.

In addition, the time-plot of BQI offers information on the behavior of beam energy at different phases of the irradiation, which is potentially valuable for monitoring the power supply stability as well as the timer error correction in radiation dosimetry.

Acknowledgement

Research was funded in part by Precision X-ray, Inc. (PXI). Thanks are due to Kevin Mastriano and Robert Hase (PXI), and Peter Leon (RTI Electronics) for technical support and measurements.