Measurement of Spontaneous Undulator Radiation Statistics Generated by a Single Electron (URSSE) Run 3 Proposal

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AST Department Meeting

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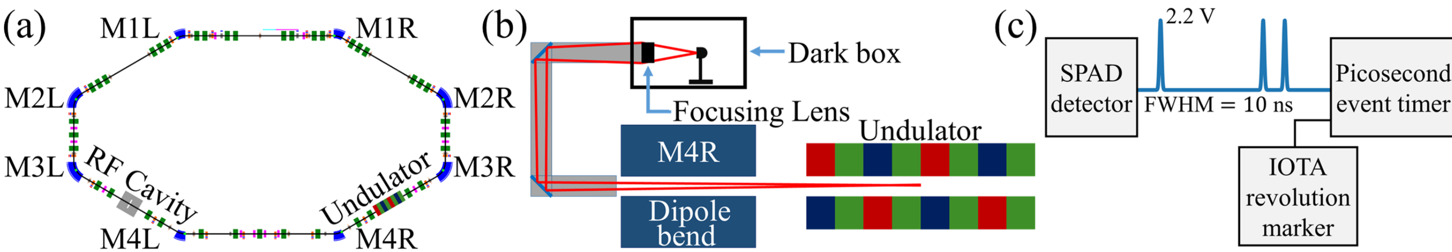
A. Halavanau, Z. Huang (SLAC)

Recap of Run 2 experiment with one SPAD

On average one detection per 304 revolutions



Revolution number	Detection time relative to revolution marker (ps)
51	62977
293	64337
674	62389
…	…

Detector: Single Photon Avalanche Diode (SPAD)

Excelitas SPCM-AQRH-10

Active area (diameter)	180 μm
Photon detection efficiency at 650 nm	65%
Dark count	~100 cps
Dead time	22 ns
Pulse height	2 V
Pulse length	10 ns

*can be reduced by using a gate (~ 5 ns)

*IOTA revolution: 133 ns

The goal of the experiment from Run 2 was to see if there are any anomalies in the photon statistics

- Collected data:
  000001000001100000000000100010000000011100000000…
  1 – IOTA revolution with a detection event, 0 - no detection.
- On average one detection per 304 revolutions
- Probability to detect a photon(s) in one revolution: $p = 0.00330$

$$F = \frac{\mathrm{var}(\mathcal{N})}{\langle \mathcal{N} \rangle}$$

F=1 – Poissonian light (very common)
F>1 – Super-Poissonian light (very common)
F<1 – Sub-Poissonian light (unusual!)

Similar previous experiment, where the Sub-Poissonian photon statistics was reported:

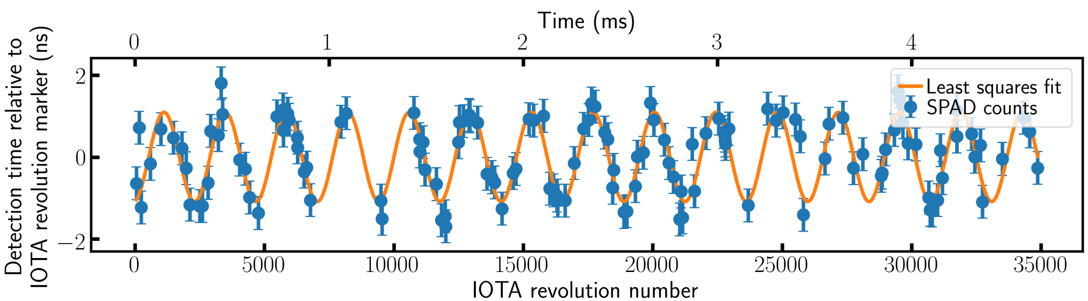
VOLUME 86, NUMBER 26 PHYSICAL REVIEW LETTERS 25 JUNE 2001

Observation of Sub-Poisson Fluctuations in the Intensity of the Seventh Coherent Spontaneous Harmonic Emitted by a rf Linac Free-Electron Laser

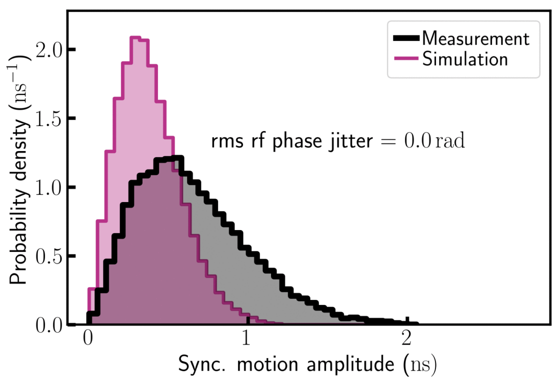
Teng Chen and John M. J. Madey
Department of Physics and Astronomy, University of Hawaii at Manoa, Honolulu, Hawaii 96822
(Received 18 April 2000)

Results of the experiment from Run 2

- No observable deviations from classical predictions
- However, the collected data can be used for diagnostics:



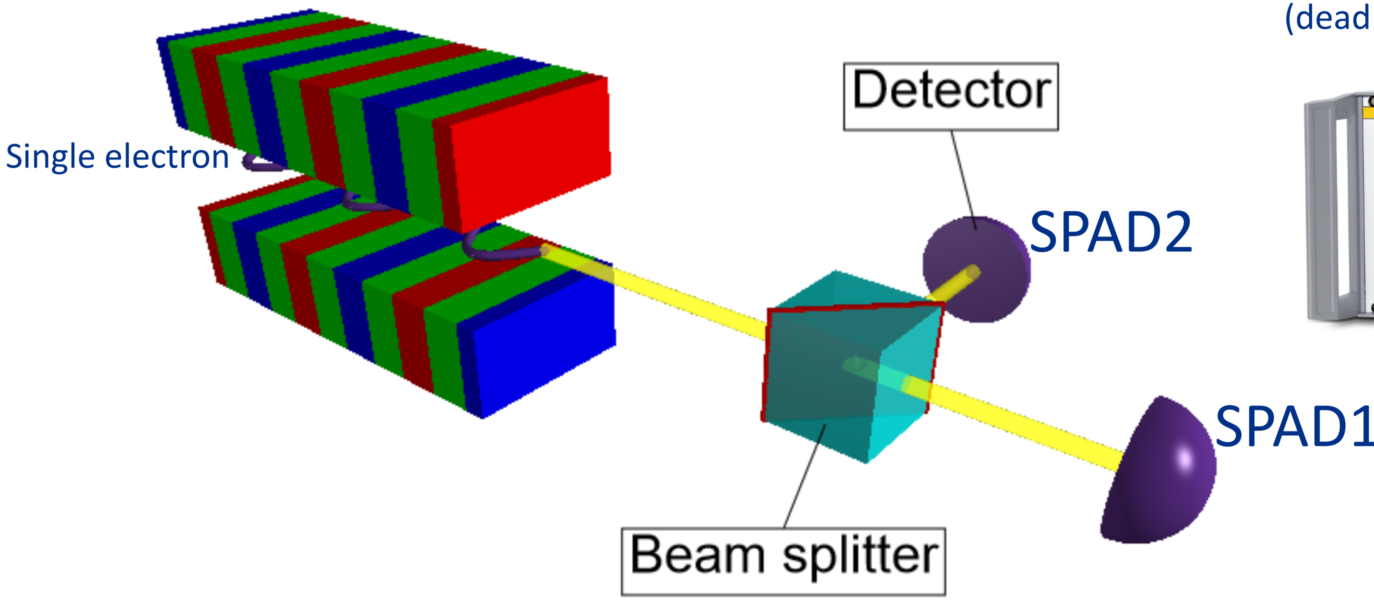
Synchrotron motion period $= 0.31$ ms



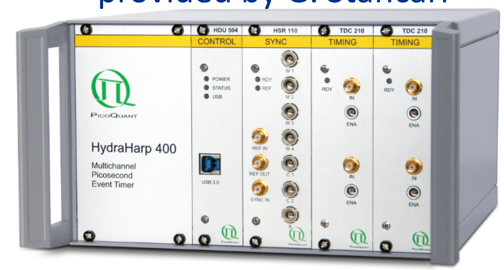
rms rf phase jitter $\approx 6\times10^{-5}$ rad

- Working on a paper for JINST or EPJ Plus, focused on the single electron synchrotron motion

Proposal for Run 3: two SPAD detectors



Picosecond event timer
(dead time < IOTA revolution period)
provided by G. Stancari



- Improved photon number resolution: {0,1} → {0,1,2}
- One of the SPADs will have an improved timing resolution 0.4 ns → 0.25 ns (purchased 50% by Sergei and 50% by Jonathan)

Proposal for Run 3: two SPAD detectors - continued

Motivation and goals:

- Will be able to measure the ratio of "single-photon" events and "two-photon" events and compare with predictions: 00000100000110000000000200010000000121 0000000…
- Will be able to measure correlation (or anticorrelation) between SPAD1 and SPAD2.

EUROPHYSICS LETTERS 15 February 1986

Europhys. Lett., **1** (4), pp. 173-179 (1986)

Experimental Evidence for a Photon Anticorrelation Effect on a Beam Splitter: A New Light on Single-Photon Interferences.

P. GRANGIER, G. ROGER and A. ASPECT (*)

Institut d'Optique Théorique et Appliquée, B.P. 43 - F 91406 *Orsay, France*

Our experimental scheme uses a two-photon radiative cascade dcescribed elsewhere [10], that emits pairs of photons with different ferequencies ν_1 and ν_2. The time intervals between the detections of ν_1 and ν_2 are distributed according to an exponential law, corresponding to the decay of the intermediate state of the cascade with a lifetime $\tau_s = 4.7$ ns.

- Will be able to take measurements with the new (faster) SPAD to obtain data of higher quality for the paper about the synchrotron motion of a single electron.
- Will prepare and fine-tune the SPAD stages for the single-electron OSC experiment.

Beam requirements

- Good beam lifetime at vanishing currents (>30 min, preferably for up to about 2 hours).
- Bunch length about 30 cm and synchrotron motion period about 0.3 ms. Variable by changing RF voltage.
- Transverse beam size on the order of 1 mm in the undulator.

Experiment regimes:

- Single electron circulating in the ring for a long time.
- Small number of electrons circulating in the ring, 1-1000. Preferably, all in one bucket.
- Nominal injection current for rough alignment (≈2 mA)

150 MeV is desirable, but 100 MeV is sufficient too.

Beam requirements - continued

If the lattice, created for this experiment, will be used for other experiments with the SLAC undulator in the future, we recommend:

- Minimums of beta-functions in the center of the undulator ($\alpha_x = \alpha_y = 0$)
- Zero dispersion in the undulator ($D_x = 0$)

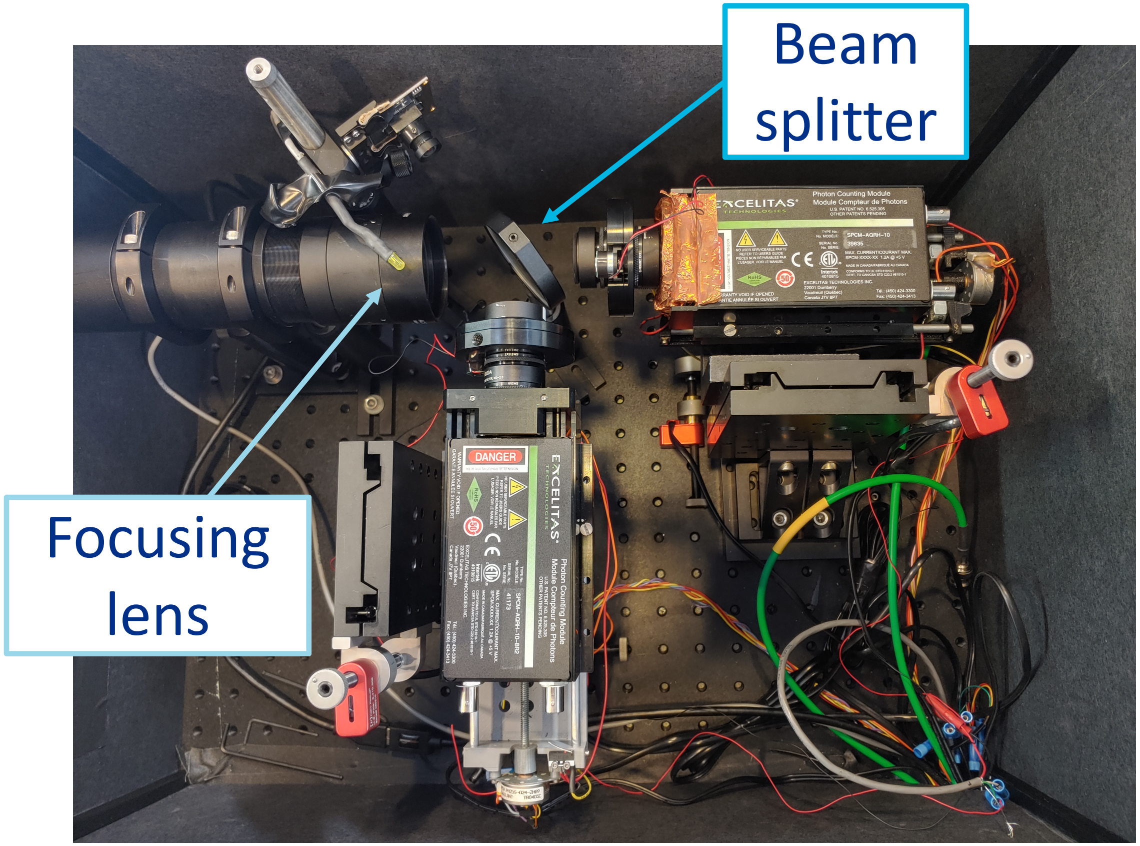
However, this is not required for URSSE.

Run plan

- **Controlled access (3-5 hrs)** to install the dark box with the new apparatus. Need two Heliax and two Ethernet cables at M4R. Also, different mirrors and a different vacuum-chamber window adapter.
- **Shift 1 (8 hrs).** Re-establish procedure to obtain 1,2,3,4,5 electrons in the ring (need Giulio). Perform alignment of the two SPADs.
- **Shift 2 (8 hrs).** Record 10-min-long data sets for 1,2,3,4,5 electrons in the ring (12000 two-detection events for 1 electron). Vary RF voltage and record data sets with 1 electron and one fast SPAD for the synchrotron motion paper.
- **Shift 3 (8 hrs).** (a few days after Shift 2) Repeat some measurements from Shift 2 if necessary. Possibly: (1) take measurements with different edge filters with undulator radiation and with bending magnet radiation (to measure spectral distribution), (2) try to record a bremsstrahlung event.

*we will require controlled accesses to move the undulator in and out.

Current status of the apparatus



It's in the Amber room now

2 Heliax ¼" cables
2 Ethernet cables

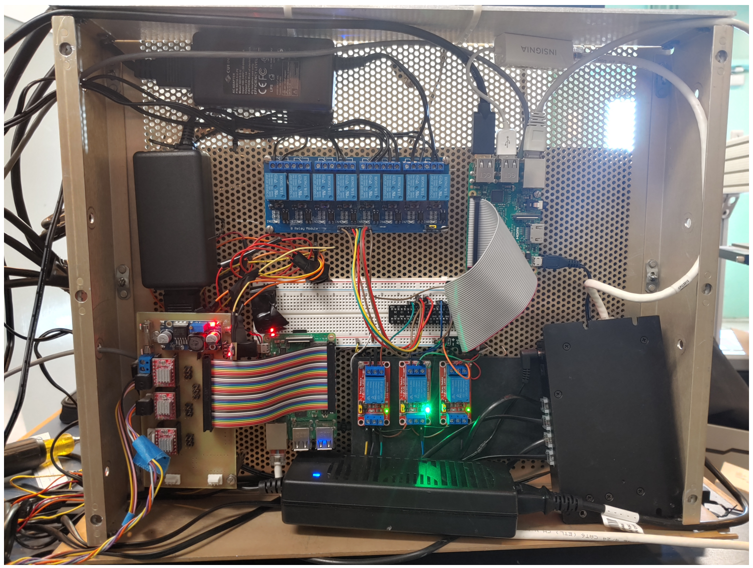
We will need to set up two rate meters for the two SPADs (Giulio, I might need your help with this).

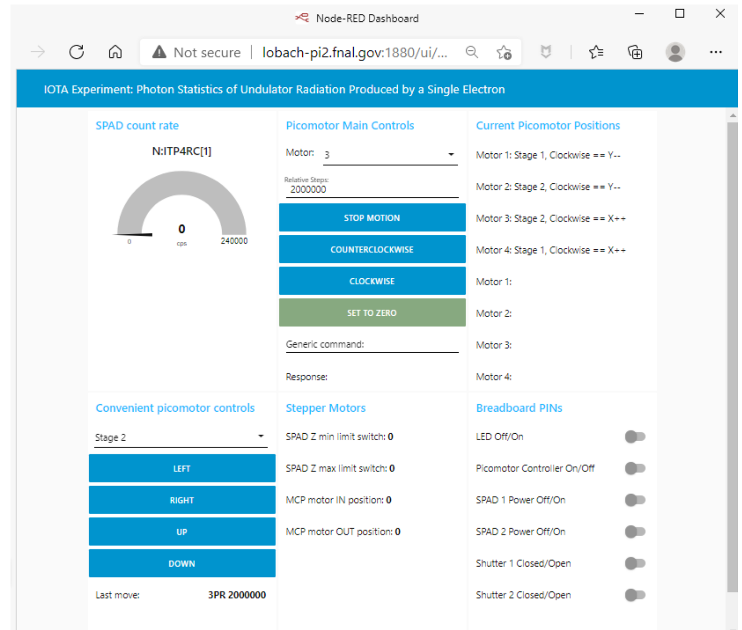
*the new faster SPAD with low dark counts (100 Hz) has not arrived yet (to my knowledge). Ordered ~ Nov 12. Lead time 12-14 weeks. Currently, one of the SPADs has dark counts rate 700 Hz, and the other 100 Hz

Current status of the apparatus - continued

<u>The controls had to be upgraded to facilitate two SPADs:</u>

picomotors 2 → 4   stepper motors 1 → 2   optical shutters 1 → 2





The stepper motors' controller is now housed in the same chassis. The controller was kindly provided by Sasha Romanov, as well as the two stepper motor stages.

Summary

If approved, the requested beam time will be used to

- Carry out photostatistics studies with an improved photon number resolution – $\{0,1\} \rightarrow \{0,1,2\}$
- Perform measurements of synchrotron motion of a single electron with the new SPAD with improved timing resolution and at several values of RF voltage to strengthen the paper for JINST or EPJ Plus. Possibly: observe bremsstrahlung scattering events.
- Prepare and test SPAD stages for the single-electron OSC experiment.

Thank you for your consideration.