

# Shot-resolved sensitive detection of high harmonics generated by bright quantum light

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## Introduction.

Strong light-matter interaction is at the heart of attosecond technologies, which brings the possibility to monitor electron dynamics at extremely short time scales [1]. One of the central phenomena of strong light-matter interaction is high harmonics generation (HHG), which results in high-frequency broadband emission at frequencies multiple to the driving field frequency [2]. However, the conversion efficiency of this process is very low and demands high sensitivity of the detector registering high harmonics.

Originally, HHG used a classical driving field, and its theoretical description ignored the quantum properties of light. The quest for quantum signatures in strong-field interaction began with the recent proposal of using bright squeezed vacuum (BSV), a quantum state of light, to pump HHG [3,4]. Unlike classical light, BSV has zero mean electric field but oscillating electric field variance. As a result, its photon number is highly uncertain (from 0 to 1012 per pulse). The nontrivial statistics of BSV are also imprinted on its high harmonics. Unlike in conventional HHG measurement, where only average signal matters, in experiments with HHG from BSV we need to measure photon numbers shot-to-shot in order to access the statistical information, such as photon number variance or photon-number cross correlation between different harmonics.

These considerations imply several requirements for the detector: high sensitivity in ultraviolet spectral range, low electronic noise, large dynamical range to capture all events without the saturation of the camera and high frame rate of acquisition.

## Experimental setup and results.

Figure 1a shows the experimental setup for generation of high harmonics by 25-fs BSV (central wavelength 1600 nm) from x-cut lithium niobate (Sample). The harmonics emission is collimated by an off-axis parabolic mirror and sent to a home-built imaging spectrometer: a magnesium fluoride prism refracts the harmonics at different output angles, which are mapped onto the positions at the sCMOS camera (Andor Marana-4BV6U) by a spherical mirror. Using an external trigger, we record 120000 spectra at 1 kHz frame rate synchronously with an infrared (IR) photodiode, which records the statistics of BSV. Such a high frame rate is achieved by selecting a region of interest 2048x40 pixels and vertical binning.

We are registering the 4th (400 nm), 5th (320 nm), 6th (266 nm) and 7th (228 nm) harmonics generated from lithium niobate. Figure 1b shows the harmonics spectra post-selected on the photon number of bright squeezed vacuum. With the increase of the post-selected photon number, we observe a blue shift of the harmonics spectrum due to the plasma generation in the sample.

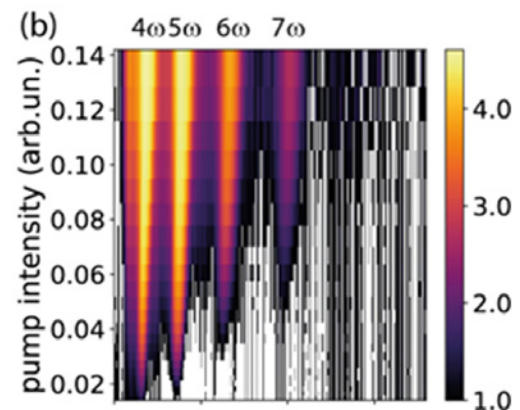
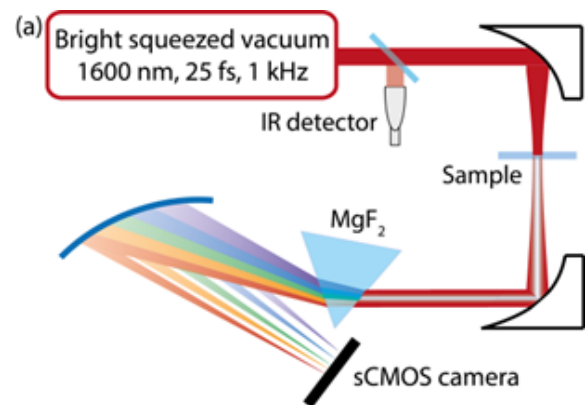


Fig 1. (a) Experimental setup for HHG driven by BSV. (b) Experimental spectra of high harmonics recorded by sCMOS camera synchronously with pump photon number fluctuations with post selection on the BSV input photon number.

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Application Note

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