# Photoemission by Multi-Photon Absorption in GaAs

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## Introduction

Spin polarized electron sources are instrumental in studying spin-dependent effects in electron-molecule and electron-atom collisions. The majority of spin polarized electron sources in use today are based on photoemission from negative-electron-affinity (NEA) GaAs and related compounds. We wish to develop better sources for polarized electrons using a novel multi-photon absorption process. Measurements of the photoemission produced by this process are presented.

## Current NEA Method

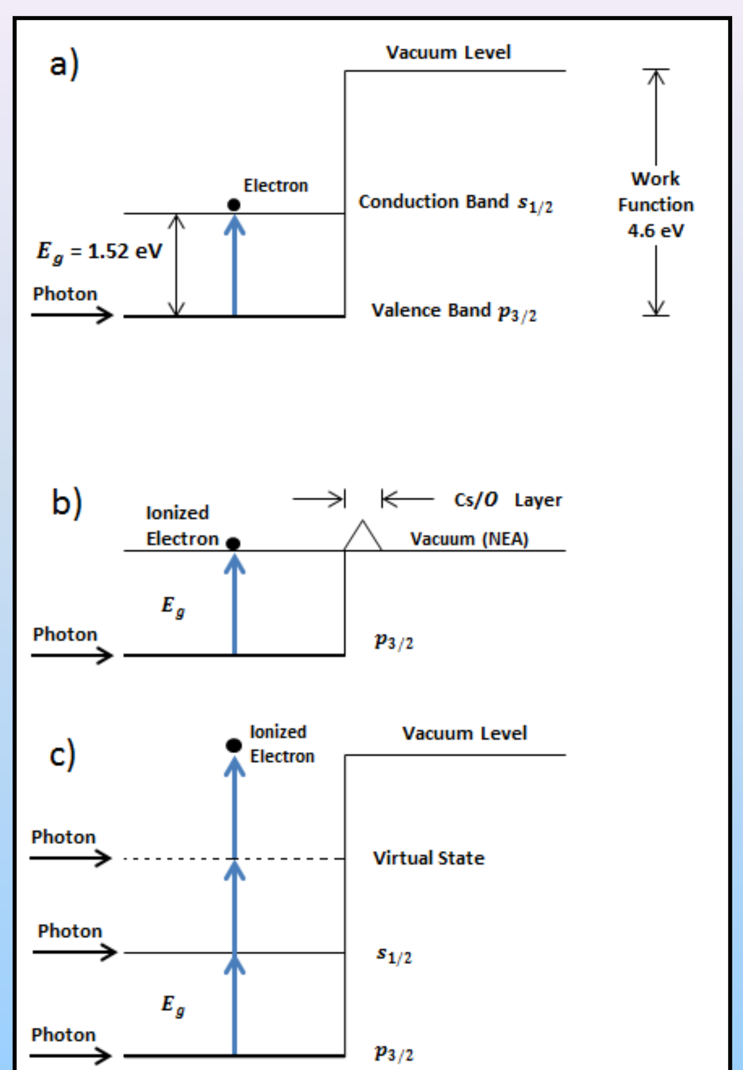


Fig.1. a) Energy bands of *p*-type GaAs with a high electron affinity and single photon absorption. b) GaAs with Cs-O treatment to produce a NEA. c) Three-Photon absorption of GaAs.

GaAs normally has a positive electron affinity, meaning the vacuum level is above the conduction band (Fig. 1 a). This prevents the electrons in the ground states from being photo-emitted by one photon. By applying layers of cesium and oxygen onto a clean GaAs crystal we can lower the vacuum level to below the conduction band, resulting in a NEA (see Fig. 1 b). When polarized light is shone onto the crystal the electrons obey certain transition probabilities; moving from the $p\downarrow 3/2$ state to the $s\downarrow 1/2$ state. NEA allows absorption of a single photon to cause photoemission. The problems included with this process include a long preparation time, activating the NEA, and maintaining a low $10^{-10}$ Torr pressure in the source chamber.

## Multi-Photon Absorption

The multi-photon absorption process is used to eliminate the need for NEA GaAs. This new process uses femtosecond pulses to excite electrons into the vacuum by three-photon absorption (see Fig. 1 c). The first photon excites the electron from the ground $p\downarrow 3/2$ state to the $s\downarrow 1/2$ state in the conduction band. A second photon excites the electron from the $s\downarrow 1/2$ state to a virtual state. Then the third photon excites the electron from the virtual state to the vacuum level, resulting in photoemission. The electrons excited state lifetime is roughly a nanosecond. Femtosecond pulses allow a lot of photons to bombard the crystal at once giving a higher probability of three photon absorption, which is why they are used to excite the electrons. This process only requires a source chamber pressure of $10^{-7}$ Torr.

## Apparatus

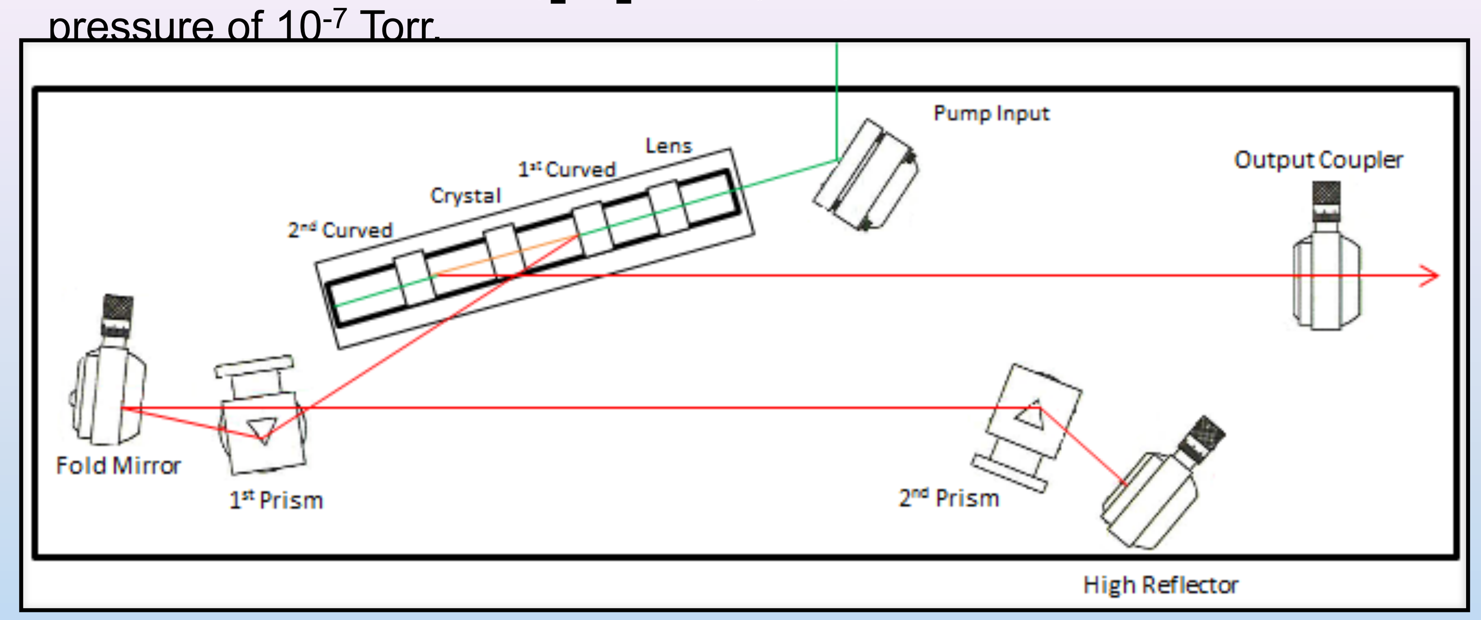


Fig. 2. A schematic of the optical system inside the femtosecond laser.

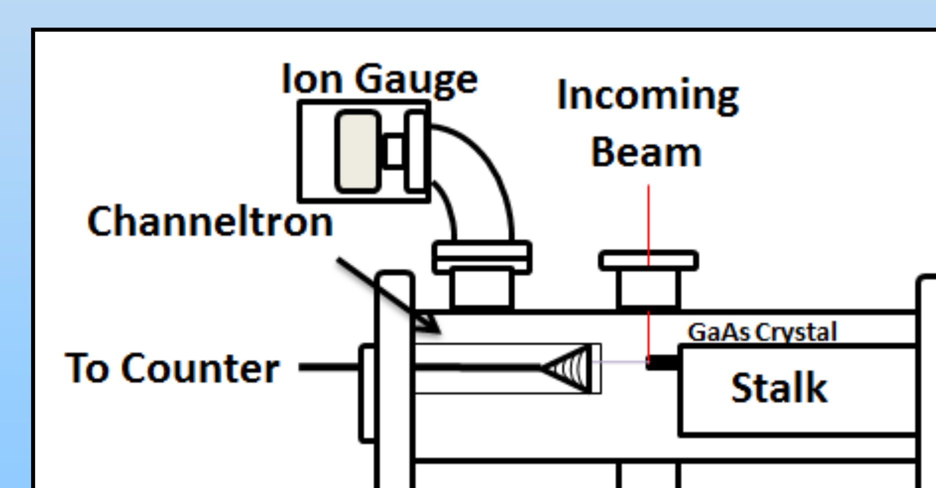


Fig. 3. Top view of the source chamber where the GaAs crystal sits. The photons enter through the side window and electrons are emitted down the Channeltron.

We use a Griffin femtosecond laser that is pumped with a Verdi V-18 CW laser: optics align and focus the femtosecond pulses onto the crystal inside the chamber. A continuous electron channel multiplier (channeltron) is used to amplify the signal of emitted electrons by sending them through a highly biased resistive glass funnel. The amplified signal is then sent to a counter where we can read the counts per second of electrons emitted by the three-photon absorption process.

## Results

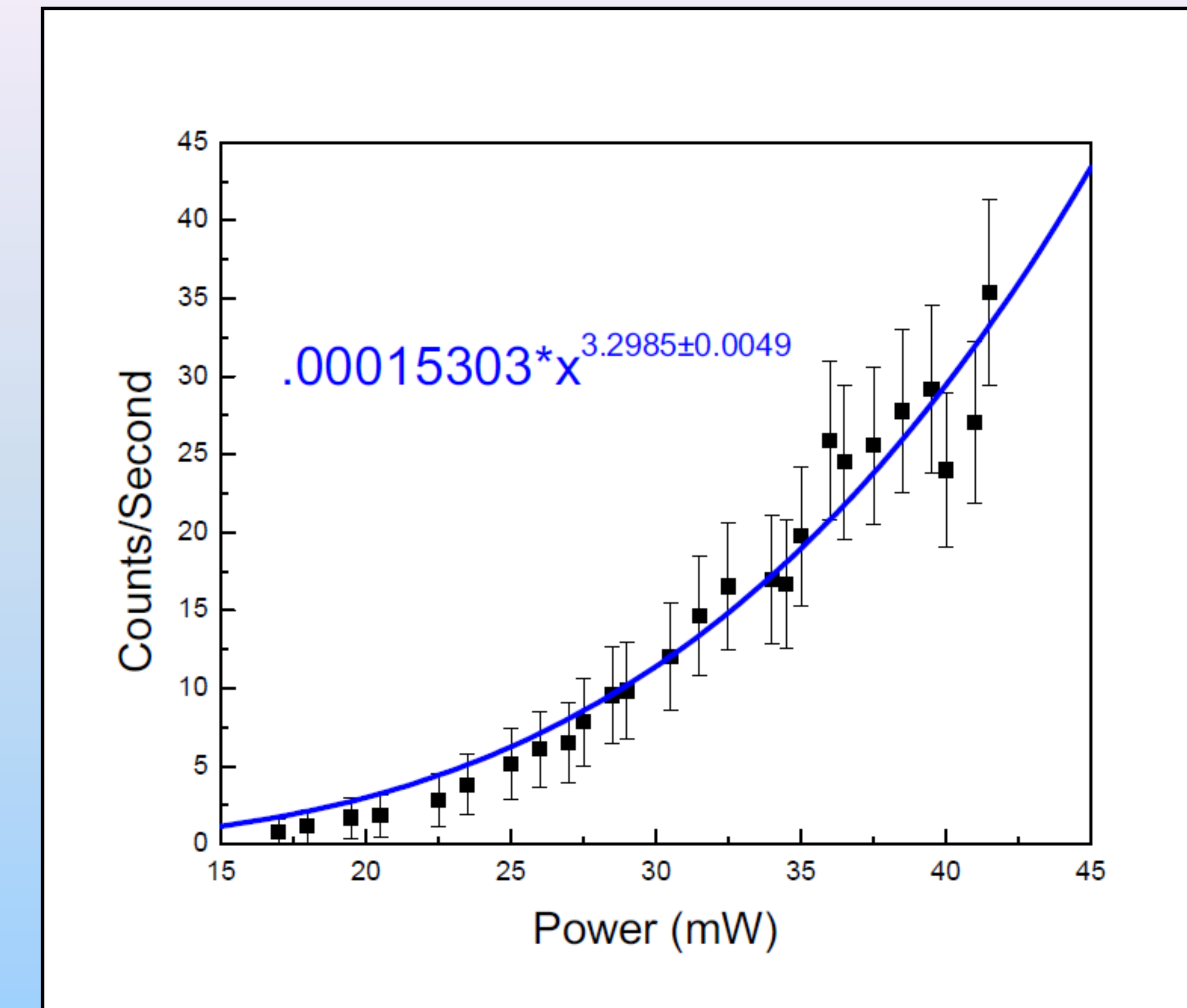


Fig. 4. Counts/second of photo emitted electrons from GaAs versus input power of femtosecond pulses. Statistical error is calculated for the data by rooting each count/sec value. A best fit line of $.00015303x^{3.29854}$ was found.

Our data gives reasonable agreement with the three-photon absorption model for GaAs. The exponent value of the best fit curve in figure 4 indicates there to be roughly three photons needed to photo-excite electrons into the vacuum. Next, after optimizing the photoemission rate we will use circularly polarized light to photo-emit the electrons. During this process we attempt to produce polarized electrons. Determining the polarization of the electrons will be done using a Mott polarimeter.

## Acknowledgements

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