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.

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 compared to single photon absorption. This new process uses femtosecond pulses to excite electrons into the vacuum by three-photon absorption (see Fig. 1 c). 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 compared to single photon absorption. This new process uses femtosecond pulses to excite electrons into the vacuum by three-photon absorption (see Fig. 1 c).

Current NEA Method
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 10⁻⁷ Torr pressure in the source chamber.

Apparatus
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
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.

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References