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SURFACE-PLASMON ENHANCED NONLINEAR PHOTOELECTRIC EMISSION FROM THIN SILVER FILMS*

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DISCLAIMER

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ABSTRACT

We report a 10^4 enhancement and quantum yield of 1.7 $\times 10^{-8}$ obtained from a 2–photon photoelectric emission of a thin silver film using surface plasmon excitation, which are resonantly pumped by femtosecond laser pulses in an attenuated-total-internal reflection configuration.

In this experiment, unamplified 100 fs CPM laser pulses are employed to couple, optically and resonantly, to the Single-Metal-boundary Surface Plasmon polaritons (SMSP) of a 430 Å thick Ag film. Because the phase velocity of the SMSP is slower than that of a photon of the same energy, direct coupling to a photon field is forbidden. However, using the Attenuated-Total-internal Reflection (ATR) geometry, this momentum matching condition is fullfilled with the aid of a glass prism by adjusting the incident angle of the incoming laser until the photon match the SMSP dispersion.[1] The experiment was performed in a vacuum chamber of 3×10^{-8} torr with an extraction voltage of 0.5 kV applied to a Cu ring anode.

Figure 1 shows the schematic of the experimental detail. The experimental and theoretical plots of the ATR spectrum at the HeNe laser wavelength for well collimated *p* and the *s* polarized beams are shown in Figure 2a. A film thickness of 430 Å and metal dielectric constant of $\epsilon_m = -17.5+i0.5$ were obtained by fitting the experimental data with Fresnel reflection and transmission coefficients. The electron emission and ATR spectrum were measured simultaneously using the CPM laser, see Figure 2b. The electron yield enhancement is evident at the SMSP resonance angle of ~43°. A logarithmic plot of the peak laser power density against the measured peak electron density is depicted in Figure 3. The slope of ~2 indicates a 2–photon like photoelectric emission. The observed width of the resonance dictated by the electron emission is narrower than that of the corresponding ATR spectrum by a factor of $1/\sqrt{2}$ also indicating a 2–photon process. The photon field interact linearly with the SMSP, therefore, the nonlinear electron emission is believed to arise from the coupling between the polariton field and the single electron state. The enhancement of photoelectric emission due to SMSP resonance over the bulk emission is demonstrated by comparing the electron yield at the SMSP resonance angle to the yield obtained by irradiating the Ag film at normal incidence from the vacuum side. Since both electron yield curves indicated a 2–photon process, direct comparison gives ~10^4 higher yield for SMSP initiated emission. The effective work function of the Ag film might have been lowered from ~4.3 eV by either surface contaminants or generation of hot electrons[3-5] by ultrashort laser pulses leading to the 2–photon process instead of 3.

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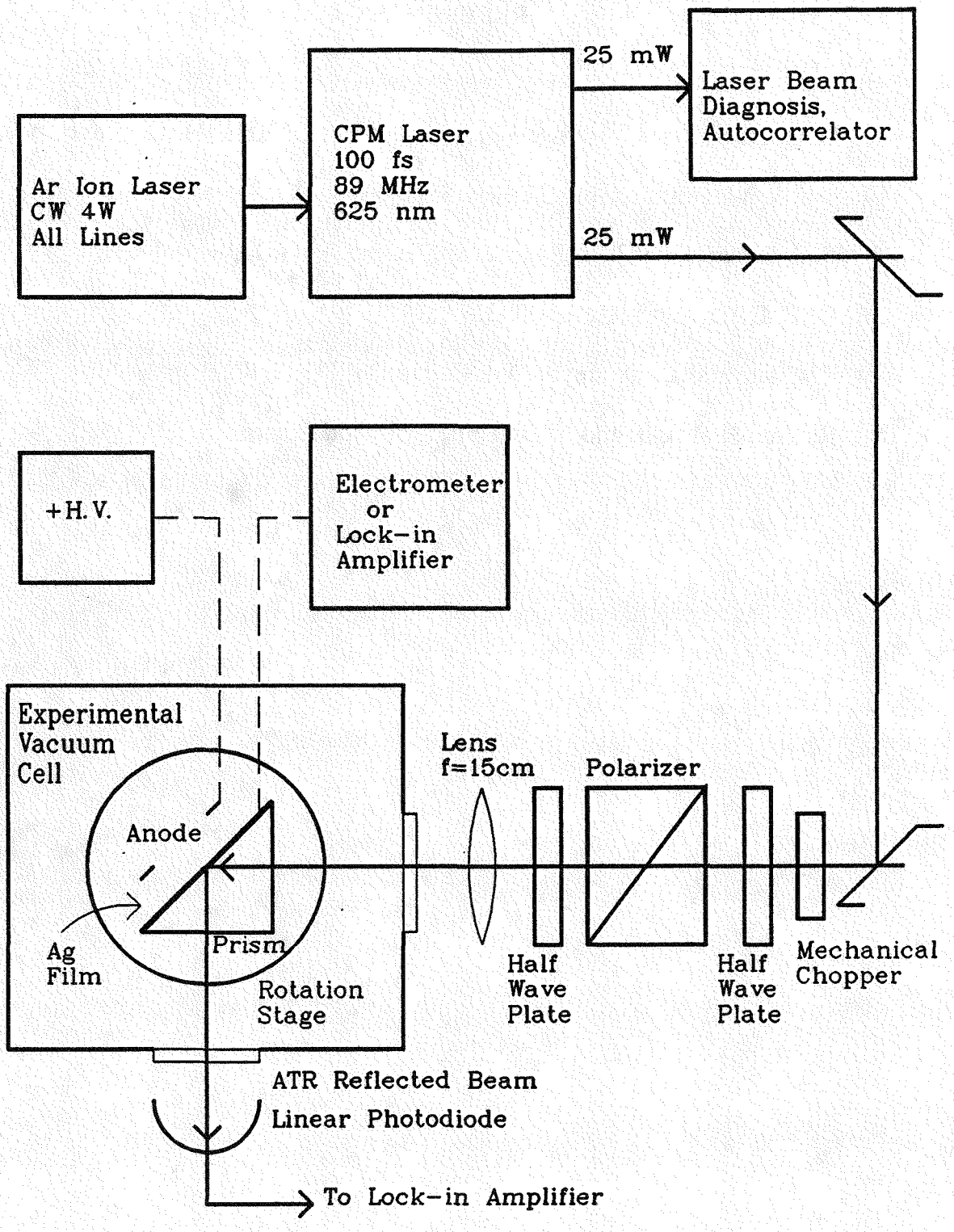

Figure 1. Experimental arrangement for the SMSP enhanced multiphoton photoelectric emission from a 430 Å thick silver film.

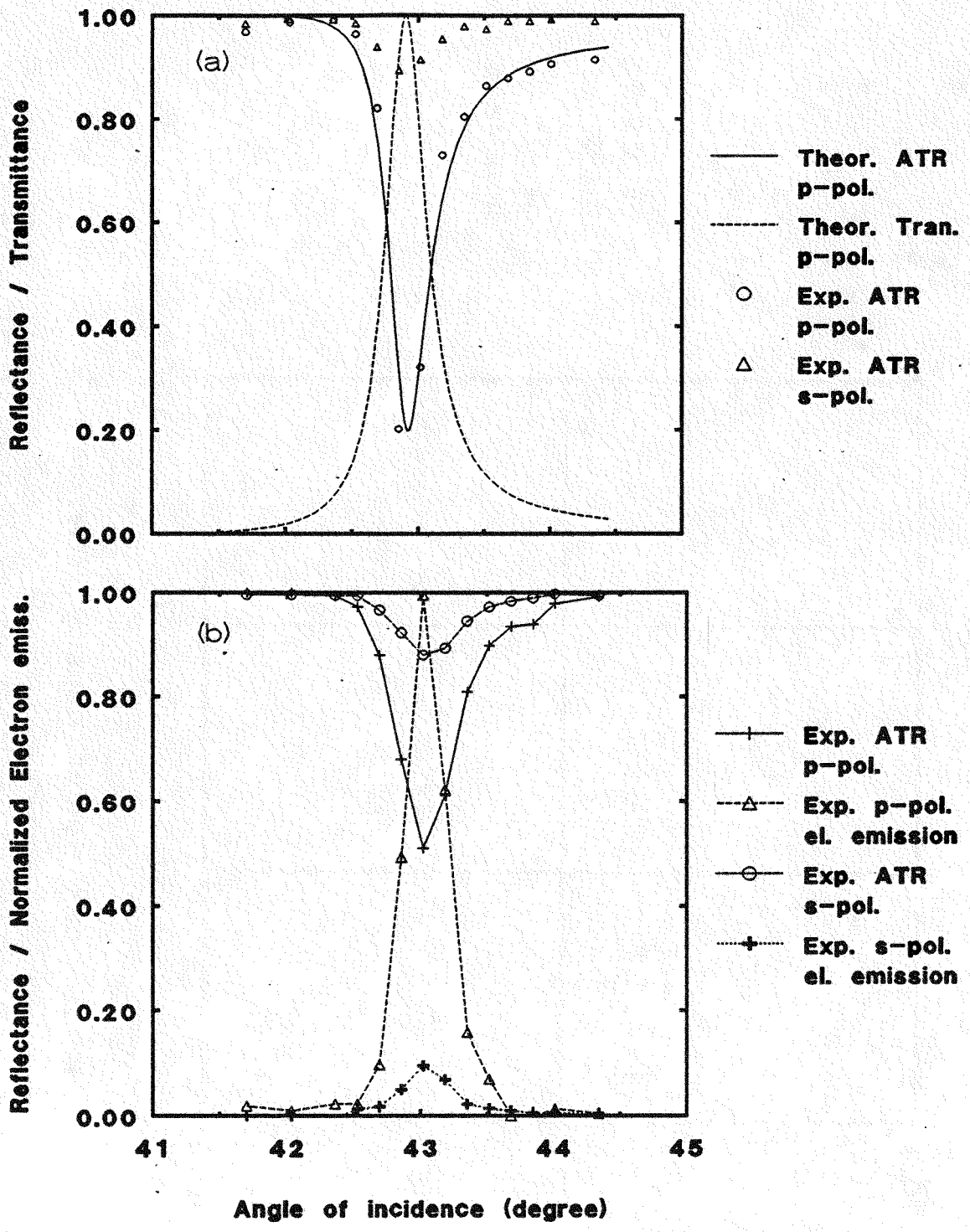

Figure 2 (a) The *p* and the *s*-polarized ATR spectrum of the SMSP using a well collimated HeNe laser. For comparison, the theoretical transmittance is also illustrated.

(b) The ATR spectrum and the electron emission of the Ag film using 100 fs laser pulses. Data points are connected for clarity.

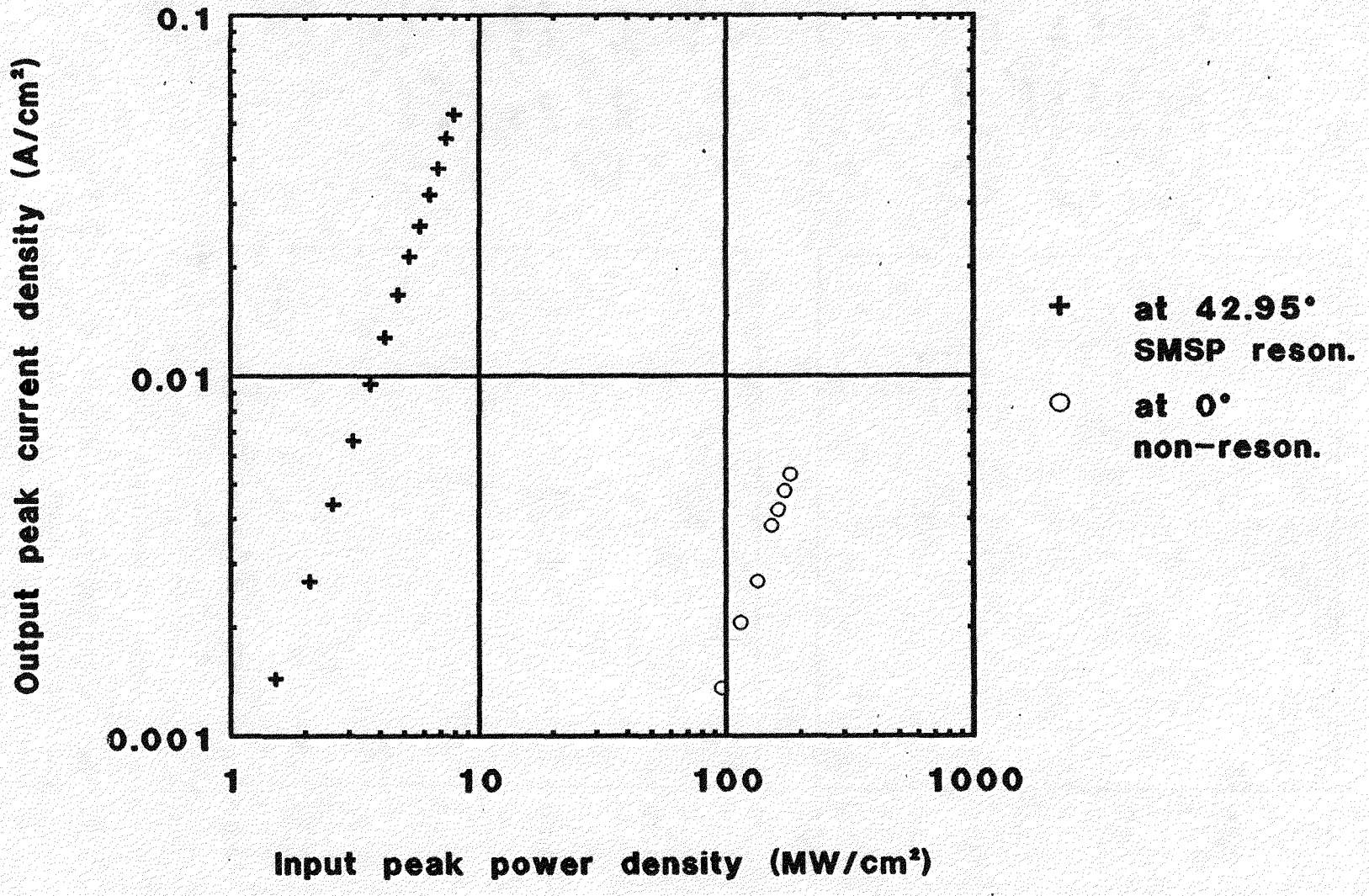

Figure 3. Peak electron current density plotted against the peak laser input power density for SMSP resonance coupling and the non-resonance excitation. The non-resonant emission is obtained by irradiating the laser at normal incident angle onto the metal film from the vacuum side.