Chapter V

POG STUDIES WITH GOLD AND PLATINUM AS TARGET ELECTRODES IN NITROGEN DISCHARGE

Introduction

POG studies of gold and platinum as target electrodes are included in this chapter. The fundamental (1064 nm) and frequency doubled (532 nm) radiations from Nd:YAG laser have been used to generate POG effect in our observations.

Some studies of photoelectric emission from gold target electrode had been carried out by earlier workers . But such studies of platinum is available very little in literature. Metals of good electric and thermal conductivity could be promising high current photoelectron sources and hence to investigate POG phenomena, gold and platinum were chosen as target electrodes in our studies.

5.1. POG Studies with gold as target electrode

The very same experimental set-up as described in the previous chapter used for POG studies with copper was used for gold target also. Pure thin gold foil of thickness 0.5 mm was sandwiched to inside of one of the discharge cell caps. Nitrogen gas is fed through a needle valve and a pressure of 180 μ bar was maintained in the discharge cell. Nitrogen was continuously flown through the cell using a rotary vacuum pump. Gold has aworkfunction of 4.68 eV [1]. Hence when 1064 nm radiations are irradiated a five photon photoemission and with 532 nm radiations a three photon photoemission can be expected in the case of gold.

Logothetis et. al. [2] observed a three photon induced photoemission from gold film using radiations from a Q-switched Ruby laser. But for higher intensities the photoemission signal was found to depend strongly on laser intensity and it was explained as due to thermionic emission resulting from heating of metal surface. Also they observed a two photon absorption with frequency doubled Ruby laser.

Farkas et. al. [3] observed mutiphoton induced photoemission from gold surface. They suggested that at relatively low intensities, thermal electron current is comparatively high, but at high enough intensity range multiphoton photoelectron current is much higher than the thermionic one giving pure photoelectron emission.

Charalambidis et al. [4] generated small divergent high electron current from gold target using KrF laser. They

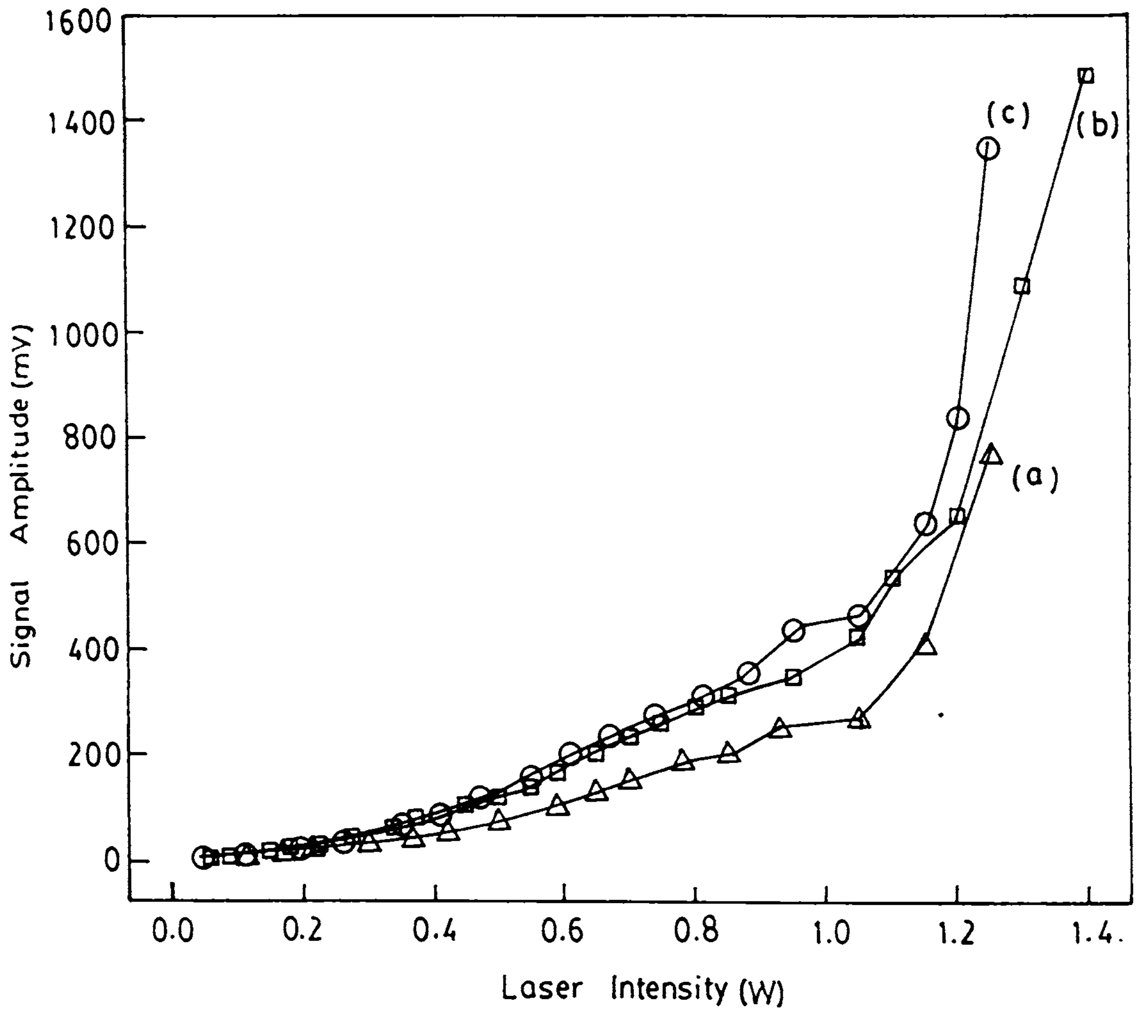


Fig.5.1. Variation of POG signal with respect to laser intensity (for gold electrode, forward biased condition) (a) - 800 V, (b) - 900 V, (c) - 1000V

rmined a threshold laser intensity below which the single on photoemission dominates on any laser induced thermionic sion process. The 4.68 eV workfunction of gold is smaller the 5 eV photon energy of KrF laser, but they observed a ar photoelectric effect only up to a certain level of laser nsity and above that the slope is found to increase. Lompre al. [5] observed a five photon induced photoelectric emission m gold using 30 p sec Nd:YAG laser.

In the present study both 532 nm and 1064 nm pulsed laser iations were used in the POG observations. Fig. 5.1 shows the endence of POG signal amplitude on laser intensity. As laser ensity is increased above a certain value, for all applied tages across the discharge cell,the signal amplitude is found shoots up sharply. With 532 nm laser pulses one can expect a ee photon induced photoemission from gold. The log-log plot of g. 5.2) POG signal amplitude against laser intensity shows a pe of nearly 2 up to a threshold laser intensity and after t the slope increases to nearly 5 for all applied voltages icating the number of photons taking part in the photoemission cess.With the applied voltage also the POG signal amplitude reases.

Many workers observed similar phenomena described above with ferent target electrodes in the absence of discharge. For mple Teich et. al.[6] with Na as target electrode using GaAs

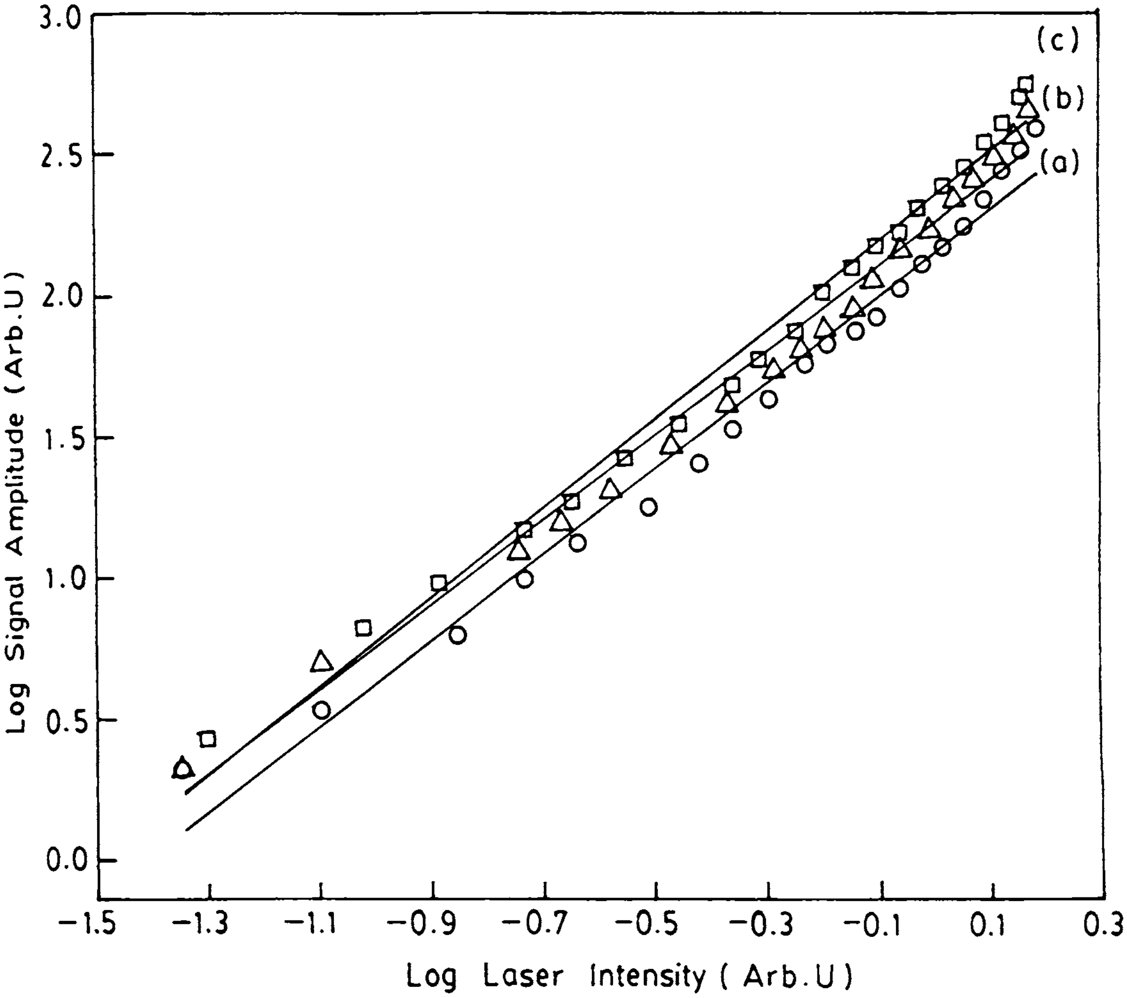


Fig.5.2. Log-log plot of POG signal amplitude versus laser intensity (for gold electrode, forward biased condition), (a) - 800 V, (b) - 900 V, (c) - 1000 V.

laser observed a linear dependence for lower laser intensities and a two photon induced photoemission after a threshold laser intensity. This is the first reported work on multiphoton photoemission. Na has a workfunction of 1.95 eV and GaAs laser radiation has a photon energy of 1.48 eV and consequently a two photon induced photoelectron emission was expected even at lower laser intensities. Teich et. al. explained this as a result of photoelectric emission from the tail of the Fermi level for lower laser intensities and at higher laser intensity level pure double quantum photoemission occurs. Charalambidis et. al. [4] also observed an increase in slope at a higher laser intensity using KrF laser. They observed a linear dependence up to a certain level of laser intensity and after that an enhancement in electron current is observed. This is also attributed to the thermionic contribution at higher intensities. Yen et. al. [7] also observed an increase in the slope rather than a decrease at higher laser intensities. But a proper reason for this phenomena was not given in this work.

The observed increase in the slope at higher laser intensities (fig.5.2) cannot be attributed to thermal contributions at higher laser intensities. If at all there is thermal contribution,the slope has to decrease as emission from an extended Fermi tail can take place due to heating of the target electrode and hence a decrease in slope is to be observed.

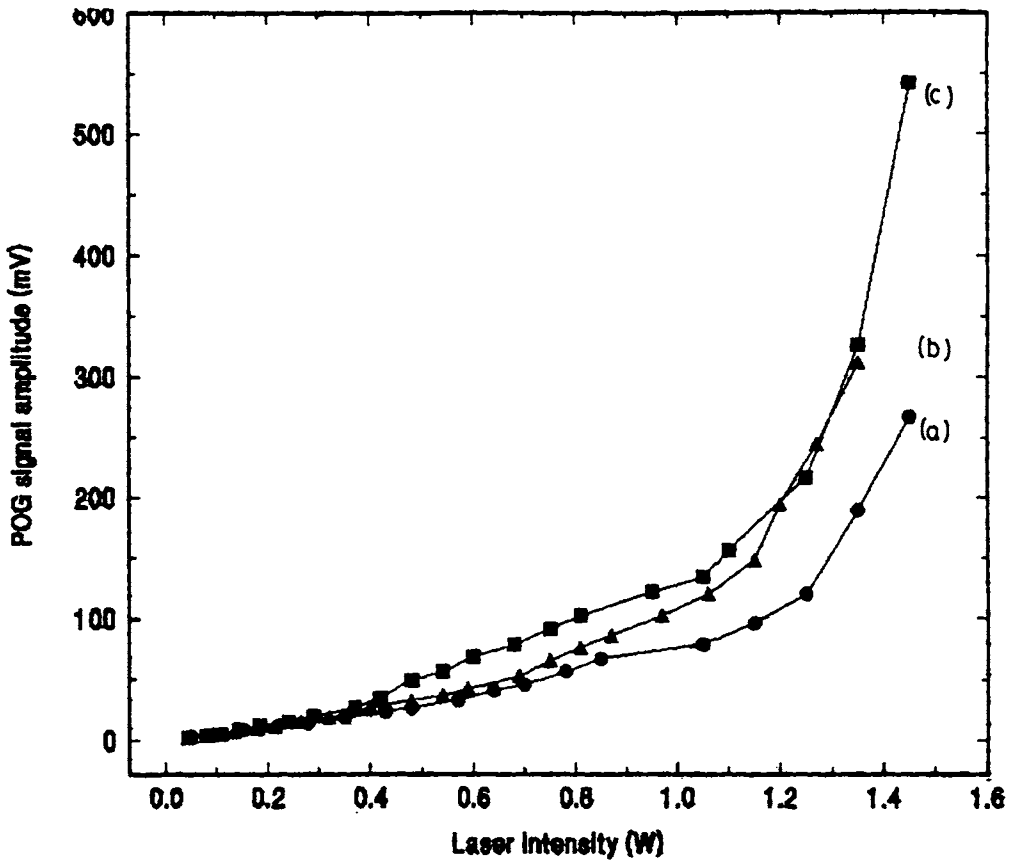
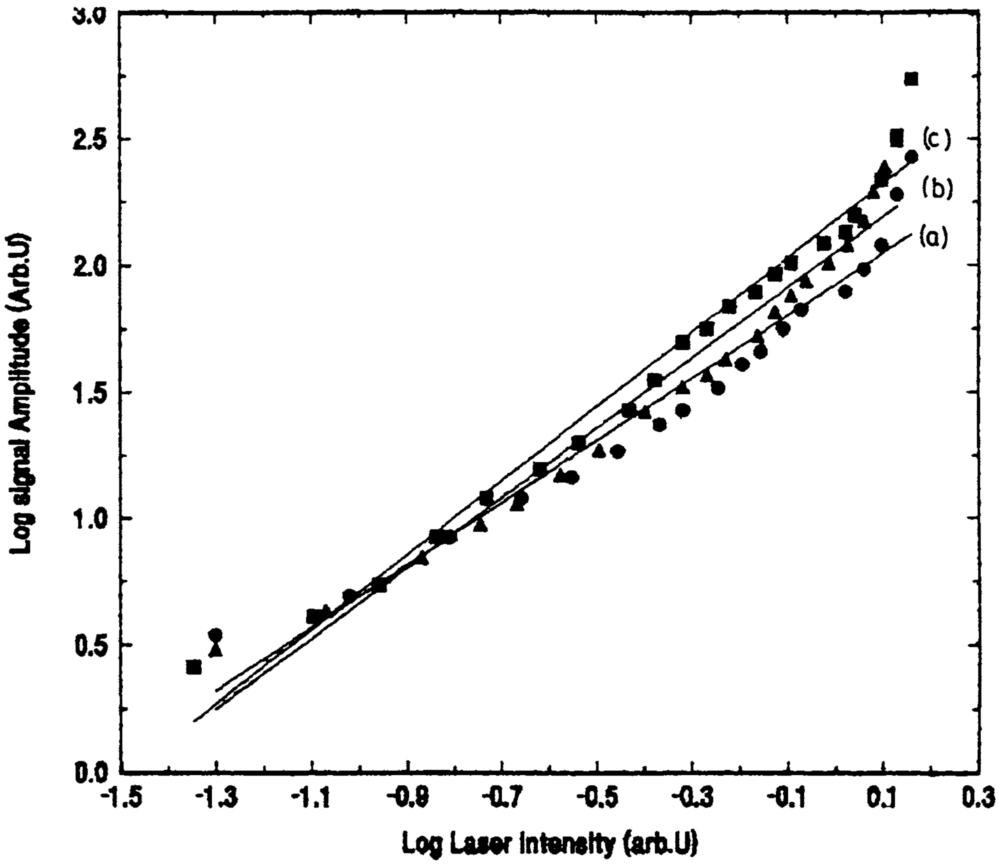


Fig 5.3. Dependence of POG signal amplitude on laser intensity (for gold electrode, reversed biased condition), (a) - 800 V, (b) - 900 V, (c) - 1000V.



.5.4. Log-log plot of POG signal amplitude versus laser ensity (for gold electrode, reverse biased condition),(a) - V, (b) - 900 V, (c) - 1000 V.

In our observation the emission of electrons with the absorption of less number of photons at lower intensity can be due to the reduction of the image potential by the presence of discharge plasma and hence the larger number of charged particles. So instead of observing three photon process, two photon induced photoelectron emission can take place. But at sufficiently higher laser intensity nonlinear phenomena like second harmonic generation [8-11] in the direction of the laser penetration may take place so as to enhance the value of slope to five as observed.

In the reverse bias case also a similar observation was made (fig. 5.3) though with comparatively lesser POG signal amplitude. Fig. 5.4 shows the log-log plot of POG signal strength verses laser intensity in the reverse biased case. Here also the slope is nearly 2 up to a particular laser intensity and after that the slope increases steeply and reaches nearly 5.

The quantum efficiency [12] of gold for 532 nm laser pulse irradiation is calculated both for forward and reverse biased conditions. The dependence of quantum efficiency on laser intensity is shown in figures 5.5. and 5.6. for reverse and forward biased conditions. In both cases the quantum efficiency considerably increases above a threshold laser intensity. No saturation as observed in the case of copper is seen in the case of gold.i.e. for high laser intensities greater photo electron

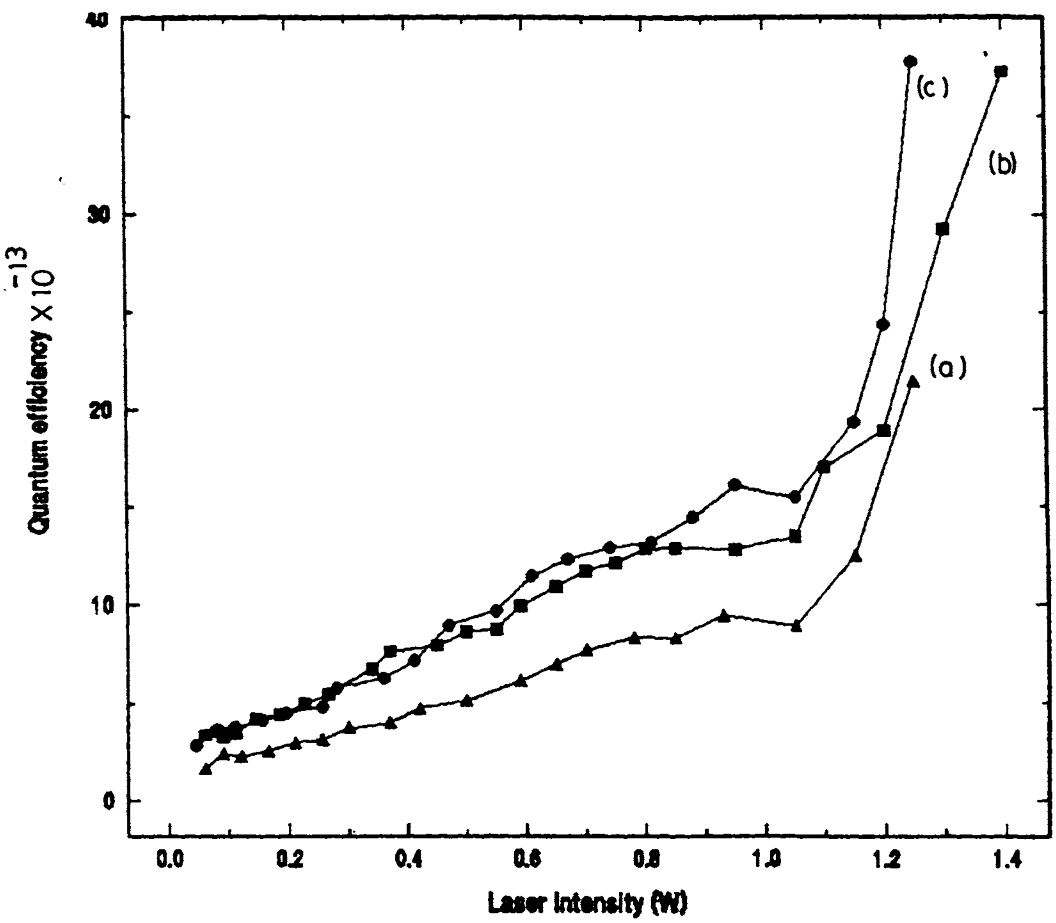


Fig.5.5 Variation of overall quantum efficiency with laser intensity (for gold electrode, forward biased condition), (a) - 800 V, (b) - 900 V, (c) - 1000V.

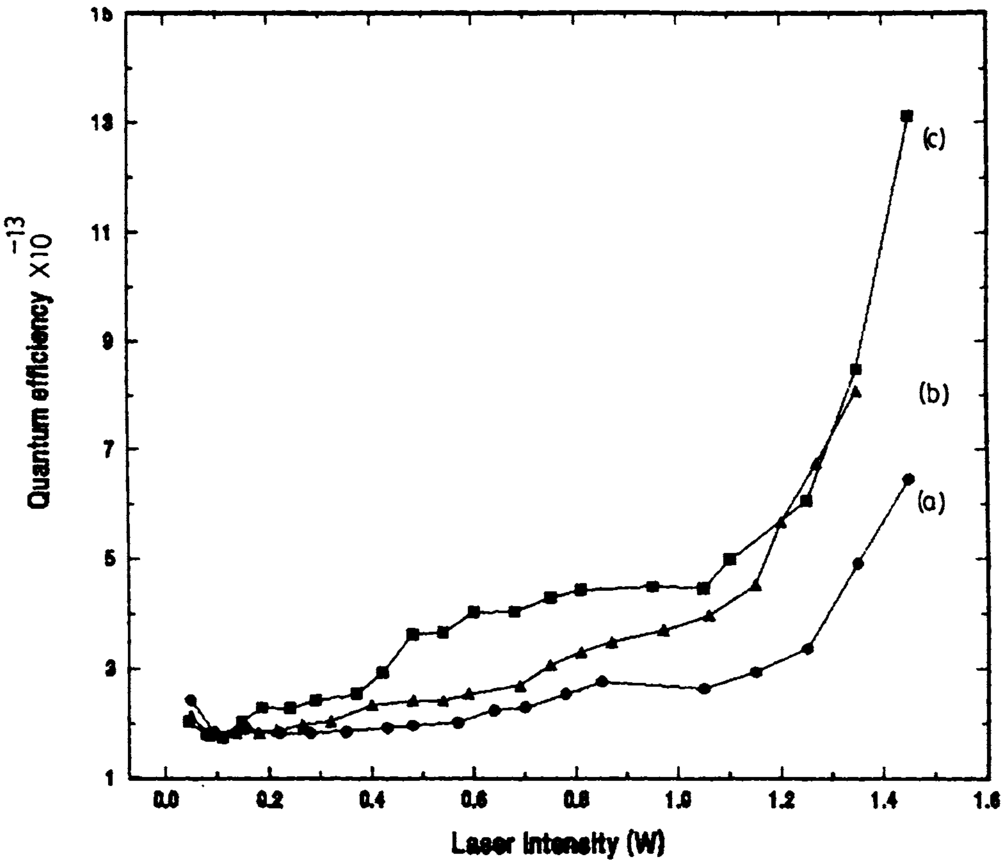


Fig.5.6. Variation of overall quantum efficiency with laser intensity (for gold electrode, reverse biased condition), (a) - 800 V, (b) - 900 V, (c) - 1000 V.

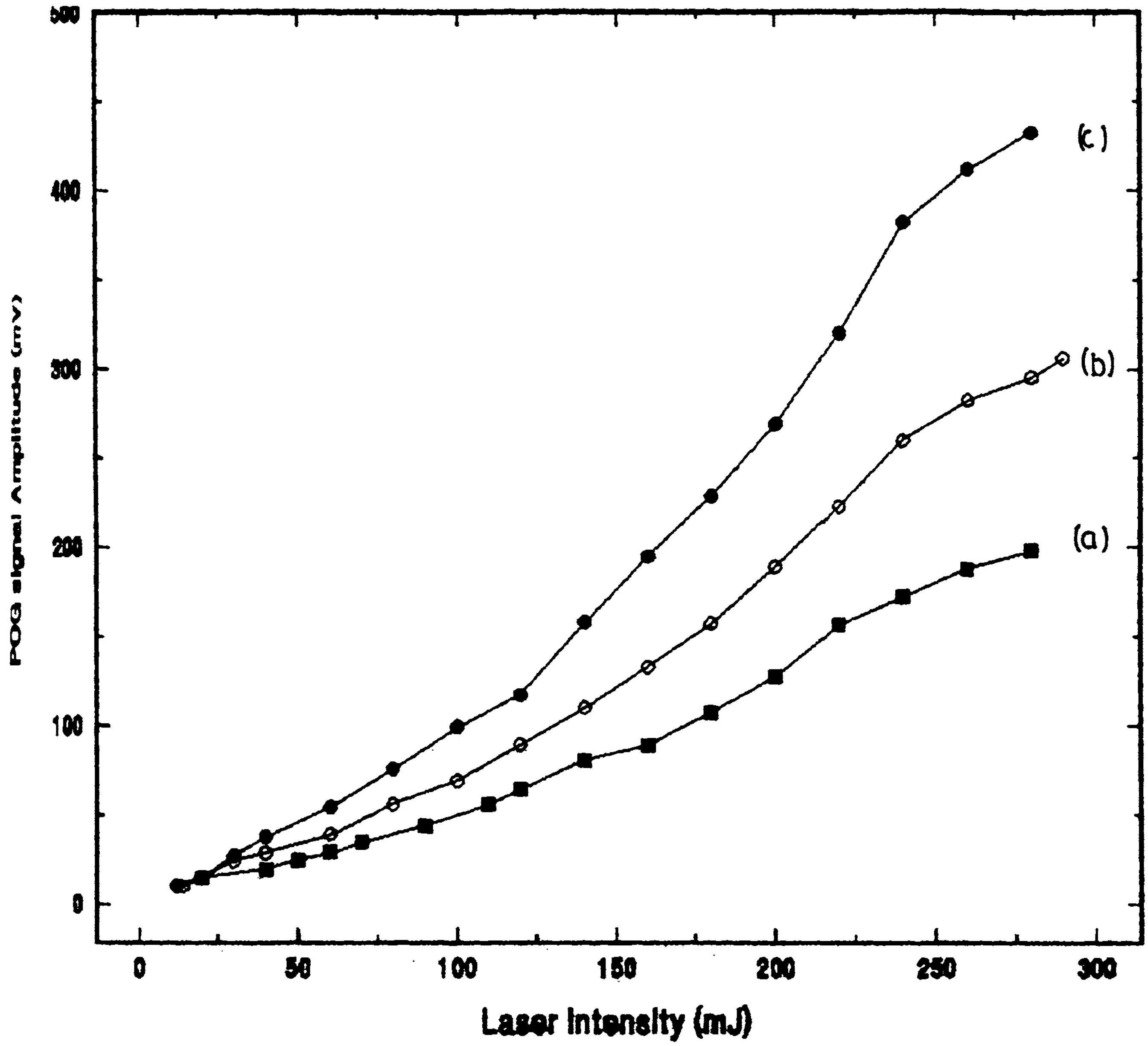


Fig 5.7. Dependence of POG signal strength on laser intensity for gold electrode using 1064 nm laser pulses, (a) - 700 V, (b) - 800 V,(c) - 900 V.

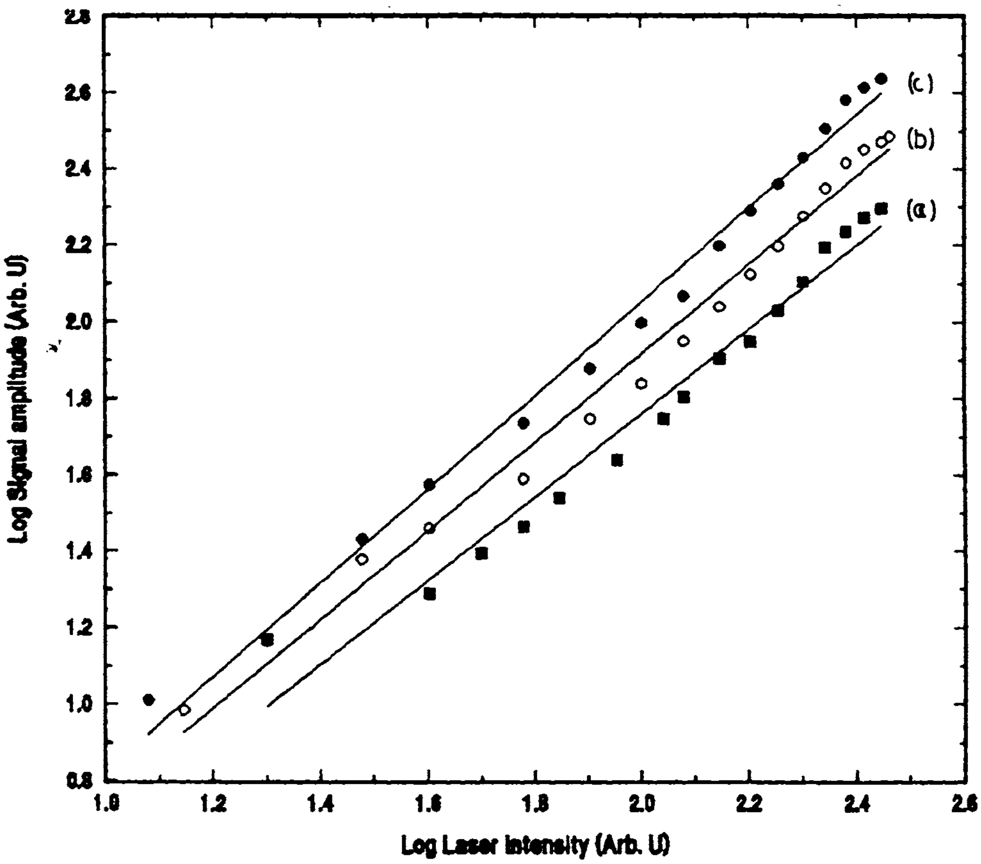


Fig.5.8. Log-log plot of POG signal amplitude versus laser intensity for gold electrode using 1064 nm laser pulses, (a) - 700 V, (b) - 800 V, (c) - 900 V.

rent can be generated from gold.

When 1064 nm radiations were used, similar results as that en 532 nm radiations used were obtained. Fig. 5.7. shows the pendence of POG signal amplitude on laser intensity using 1064 laser radiations. Fig 5.8. shows the log-log plot of signal plitude against laser intensity indicating the number of otons taking place in POG process. With 1064 nm laser diations (photon energy ~ 1.16 eV) one can expect a five photon duced photoemission. But due to heating of the target with frared radiations emission from the tail of the Fermi level can ake place [13] giving a same result as that with 532 nm laser adiations.

.2. POG studies with platinum as target electrode.

Instead of gold, a platinum foil of thickness 0.6 mm was sandwiched in the inside of one of the caps of the discharge cell. In the present case also POG studies were carried out in nitrogen discharge.

Platinum is a very good conductor with a workfunction of 5.32 eV [14]. In the present studies platinum showed almost the same observation as that with gold as target electrode.

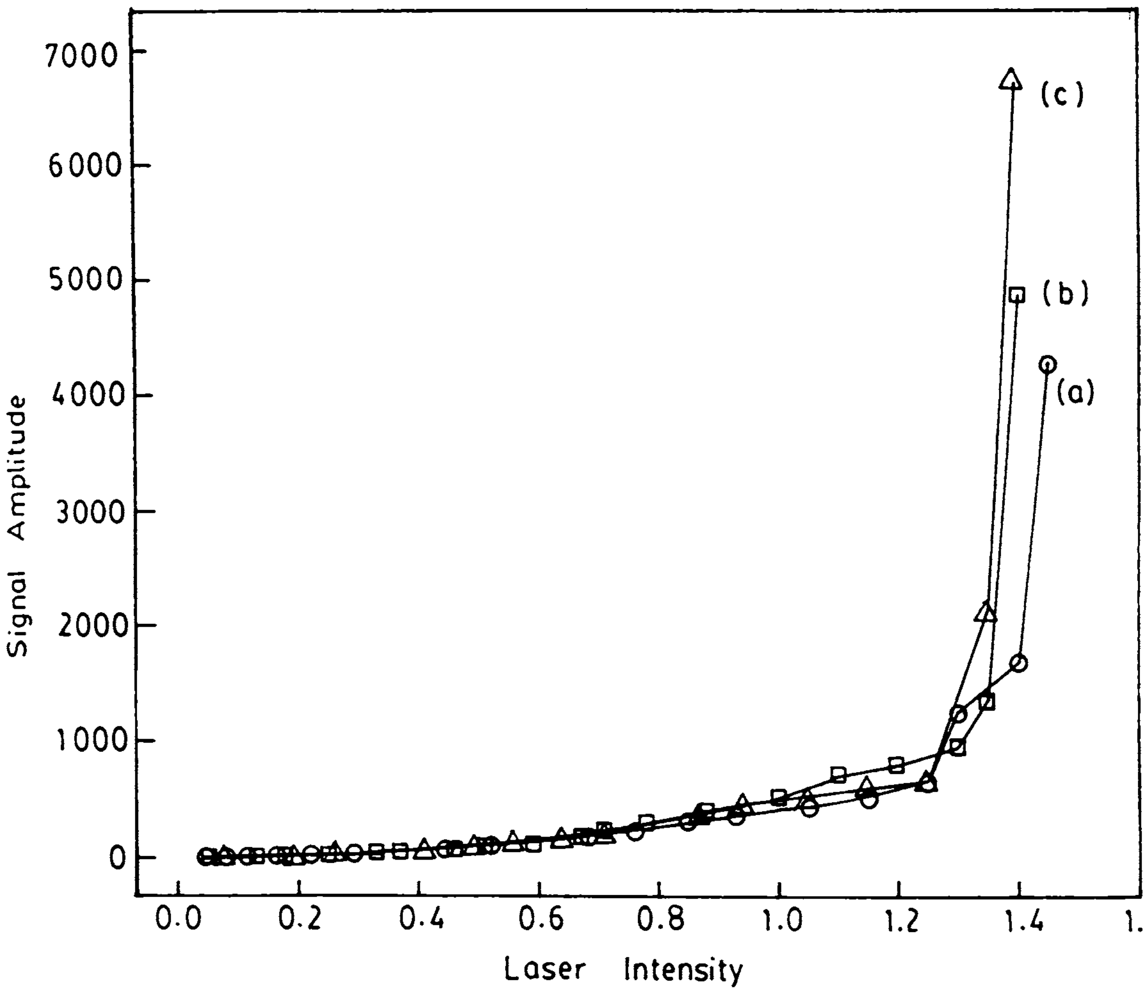


Fig. 5.9. Dependence of POG signal amplitude on laser intensity for platinum electrode (forward bias), (a) - 800 V, (b) - 900 V, (c) - 1000 V.

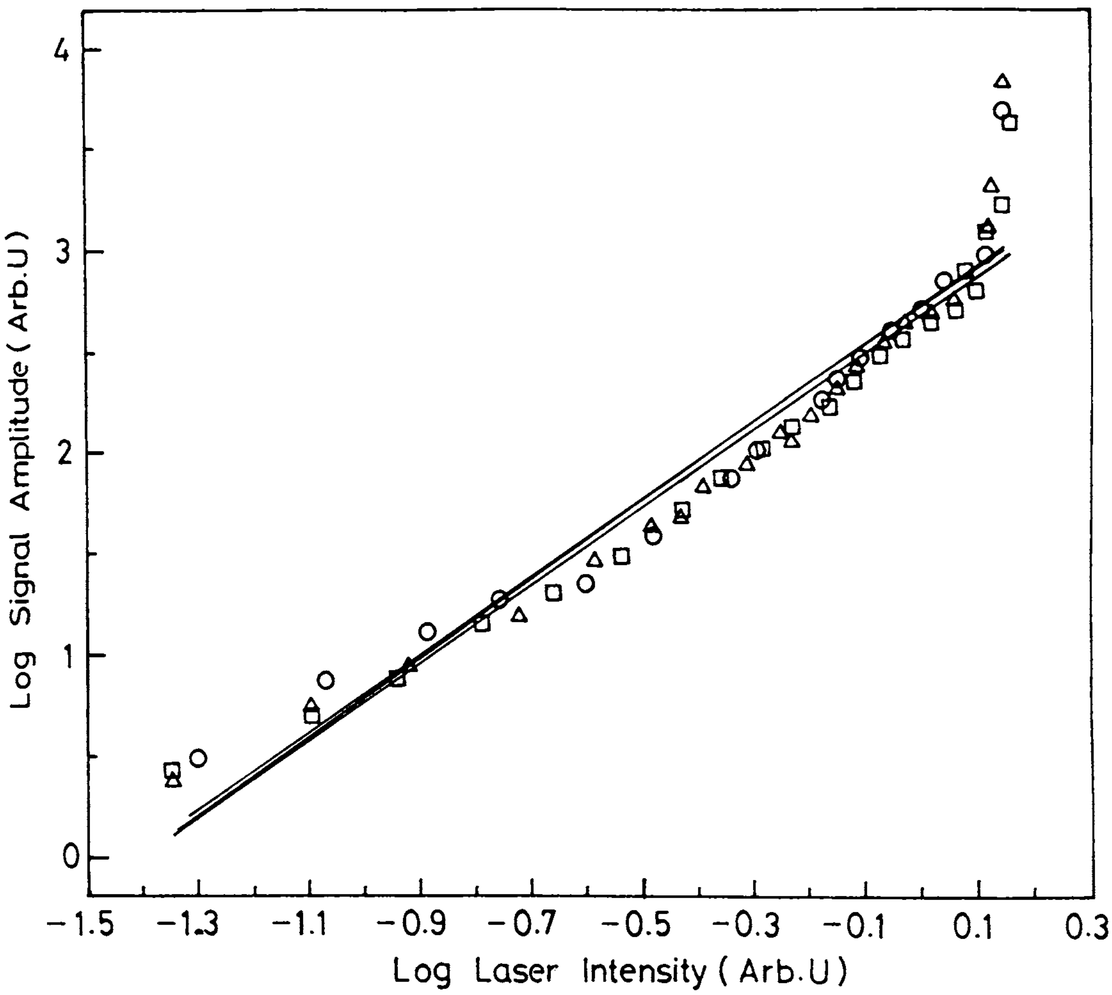


Fig.5.10 Log-log plot of POG signal strength versus laser intensity for platinum electrode (forward bias), (a) - 800 V, (b) - 900 V, (c) - 1000 V.

Only few photoemission studies had been carried out with platinum. J.F.Ready [15] had observed photoemission from platinum using a spinning prism Q-switched Ruby laser.

With frequency doubled 532 nm (photon energy ~ 2.32 eV) one can expect a three photon induced photoemission and using the Nd:YAG fundamental,1064 nm (photon energy ~ 1.16 eV) one can expect a five photon induced photoemission from platinum electrode.

The same phenomena shown by gold as described in the earlier section is found to be repeated in the case of platinum also. The dependence of POG signal amplitude on laser intensity for 532 nm laser pulses are shown in fig 5.9. for different applied discharge voltages. As the laser intensity increases POG signal amplitude also increases,but after a threshold of laser intensity the POG signal strength sharply shoots up and reaches several tens of volts. Compared to the POG signal with gold as target electrode the POG signal strength for platinum is relatively high. The log - log plot of signal amplitude versus laser intensity (fig.5.10.) gives a slope of nearly 2 up to a level of laser intensity and above that the slope goes beyond 5. With the applied voltage also there is an increase in POG signal amplitude. For photoelectric emission studies such a phenomena was observed by many [4,6,7], as mentioned earlier.

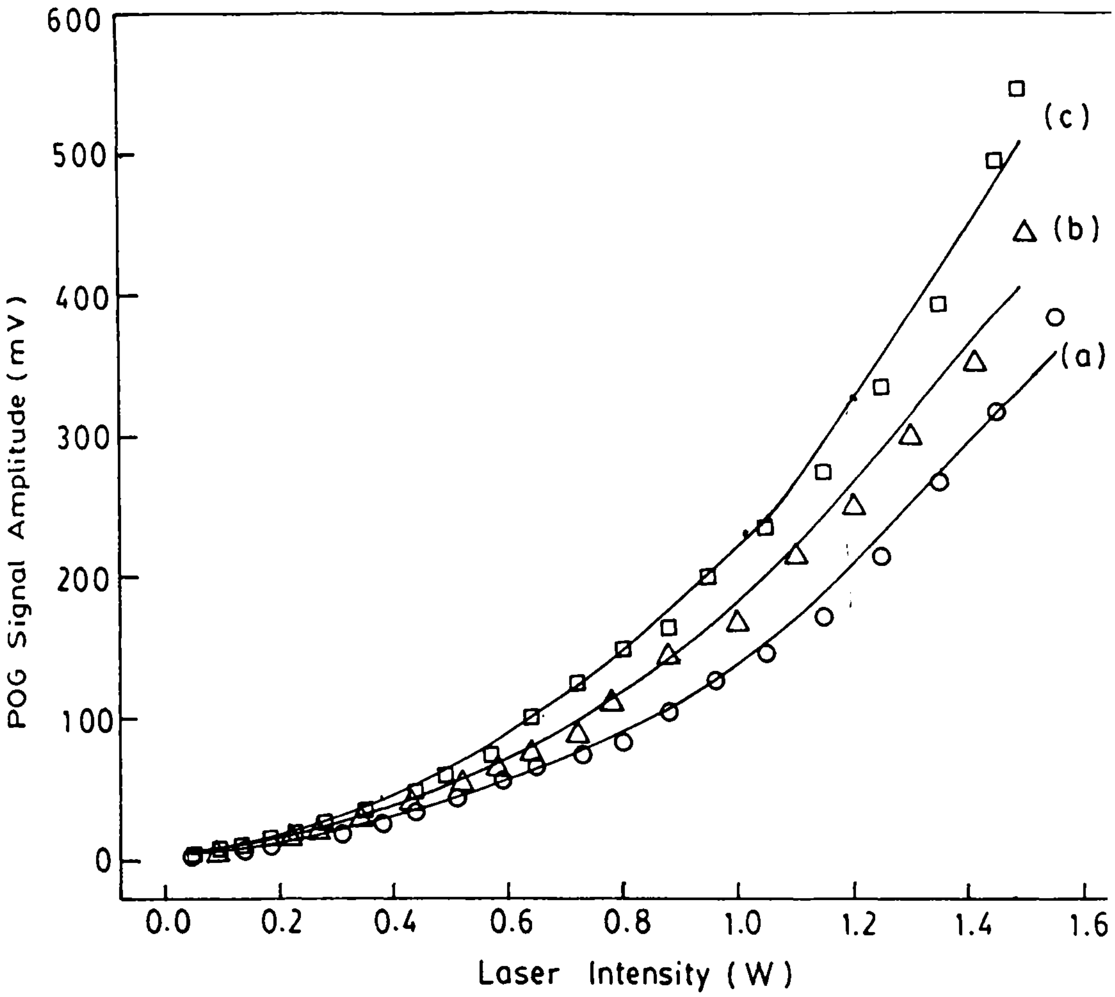


Fig.5.11. Variation of POG signal amplitude with respect to laser intensity for platinum electrode in the reverse biased condition, (a) - 800 V, (b) - 900 V, (c) - 1000 V.

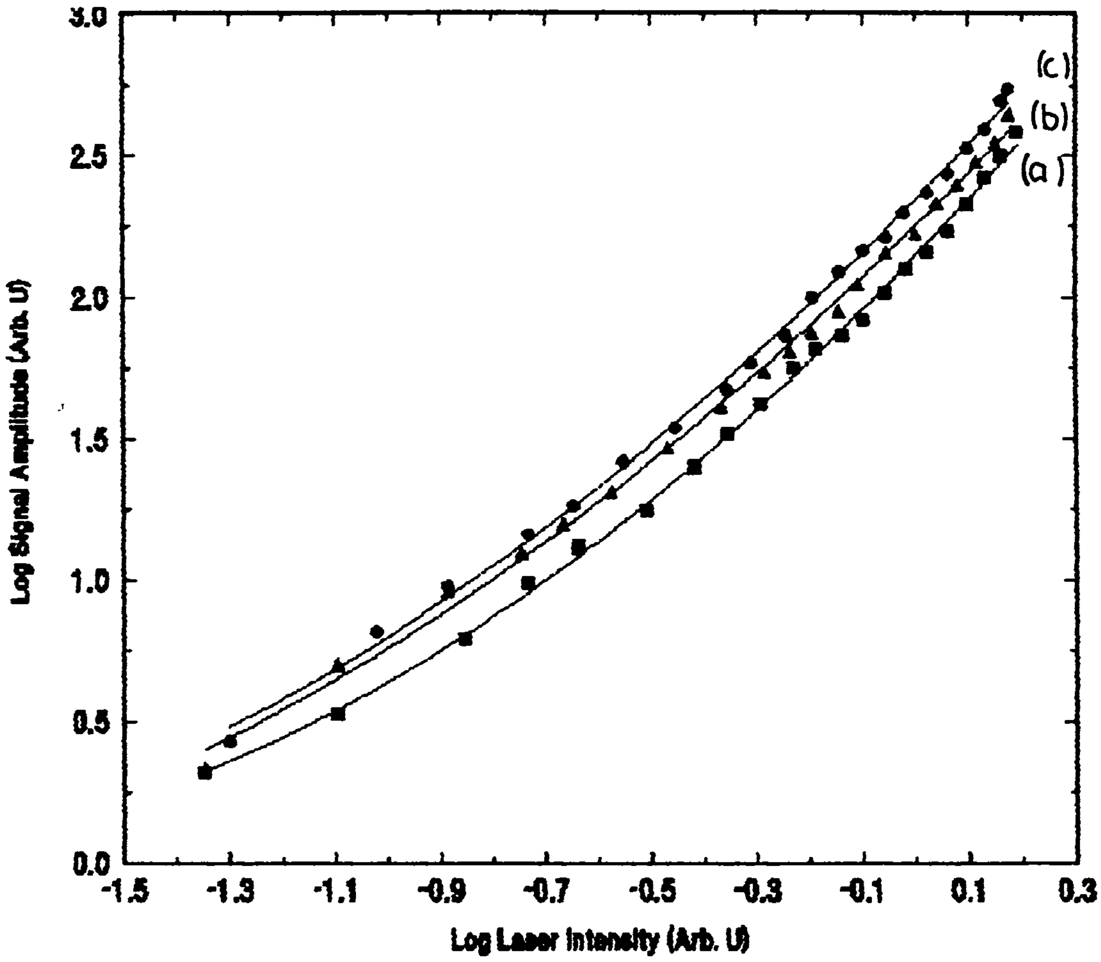


Fig.5.12. Log-log plot of POG signal strength versus laser intensity for platinum electrode (reverse bias), (a) - 800 V, (b) - 900 V, (c) - 1000 V.

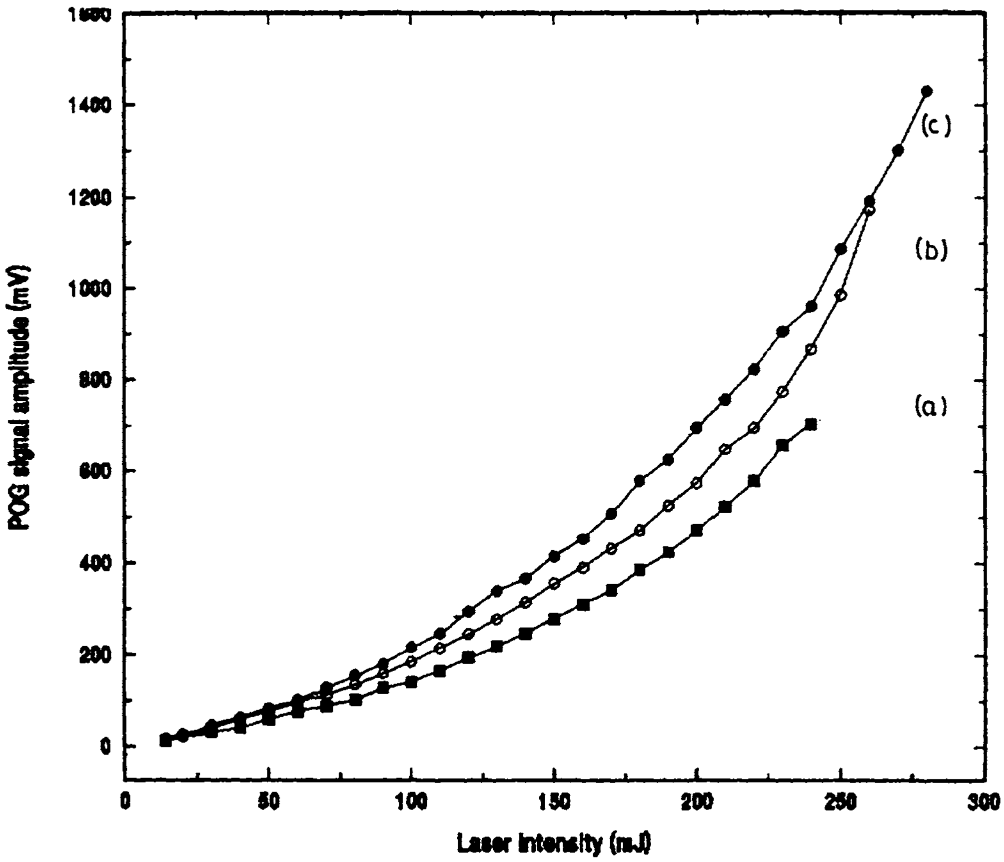


Fig.5.13. Dependence of POG signal amplitude on laser intensity with 1064 nm laser pulses using platinum electrode, (a) - 800 V,(b) - 900 V, (c) - 1000 V.

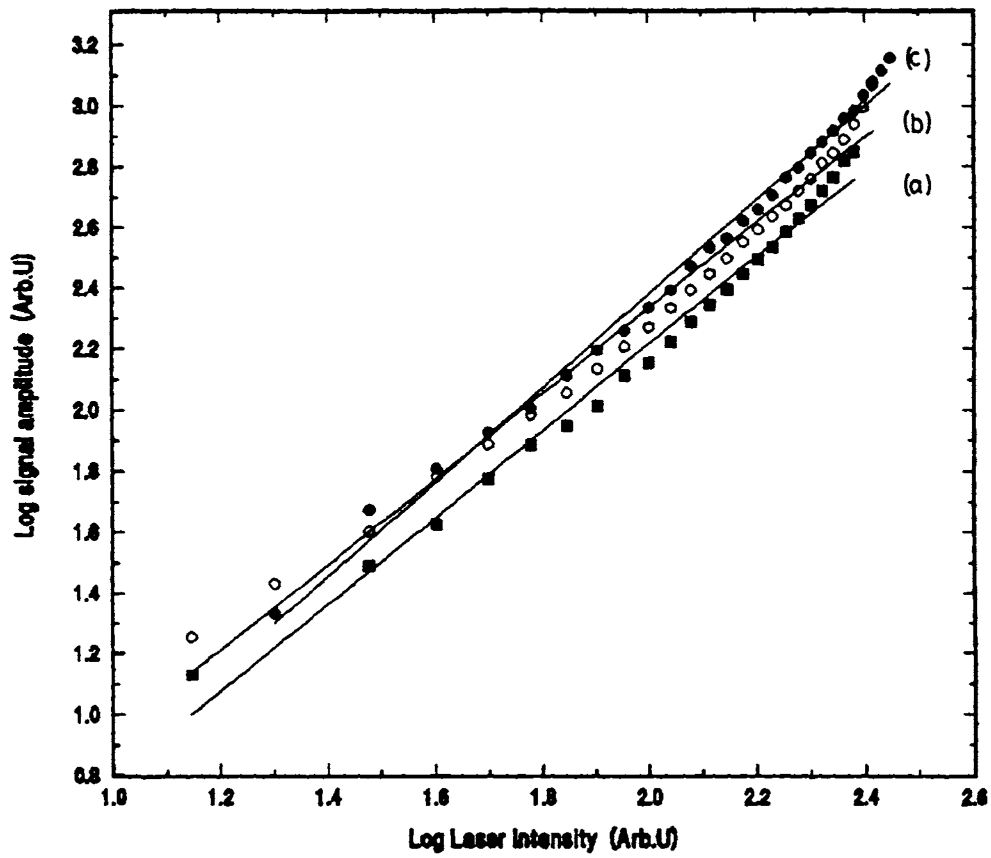


Fig. 5.14. Log - Log plot of POG signal strength versus laser intensity with platinum electrode using 1064 nm, (a) - 800 V, (b) - 900 V, (c) - 1000 V.

The probable explanation that can be given as described in the observation with gold is that the presence of ions and electrons in the discharge plasma may lower the image potential and thereby reducing the effective workfunction of platinum and hence the observation of a slope of nearly 2 in the lower range of laser intensity. As the laser intensity increases there can be second harmonic generation [8-11] in the direction of propagation of the laser pulses and a hence a higher number of photons were absorbed for electron emission.

For reverse bias case the POG signal amplitude is comparatively low (fig.5.11), but log - log plot (fig.5.12) of POG signal amplitude with laser intensity gives almost a same measurement of the number of photons taking place in the POG process as in the forward bias case.

With 1064 nm,the fundamental emission from Nd:YAG laser,also showed almost the same POG observation as with 532 nm laser pulses. Fig 5.13. shows the dependence of POG signal amplitude on laser intensity with 1064 nm laser pulses for different applied voltages. With the applied voltage as well as with the laser intensity POG signal amplitude increases. But after a threshold of laser intensity the POG signal amplitude sharply grows. The log - log plot of POG signal amplitude versus laser intensity is given in fig.5.14. For the lower range,below the threshold laser intensity, the plots have a slope of nearly 2

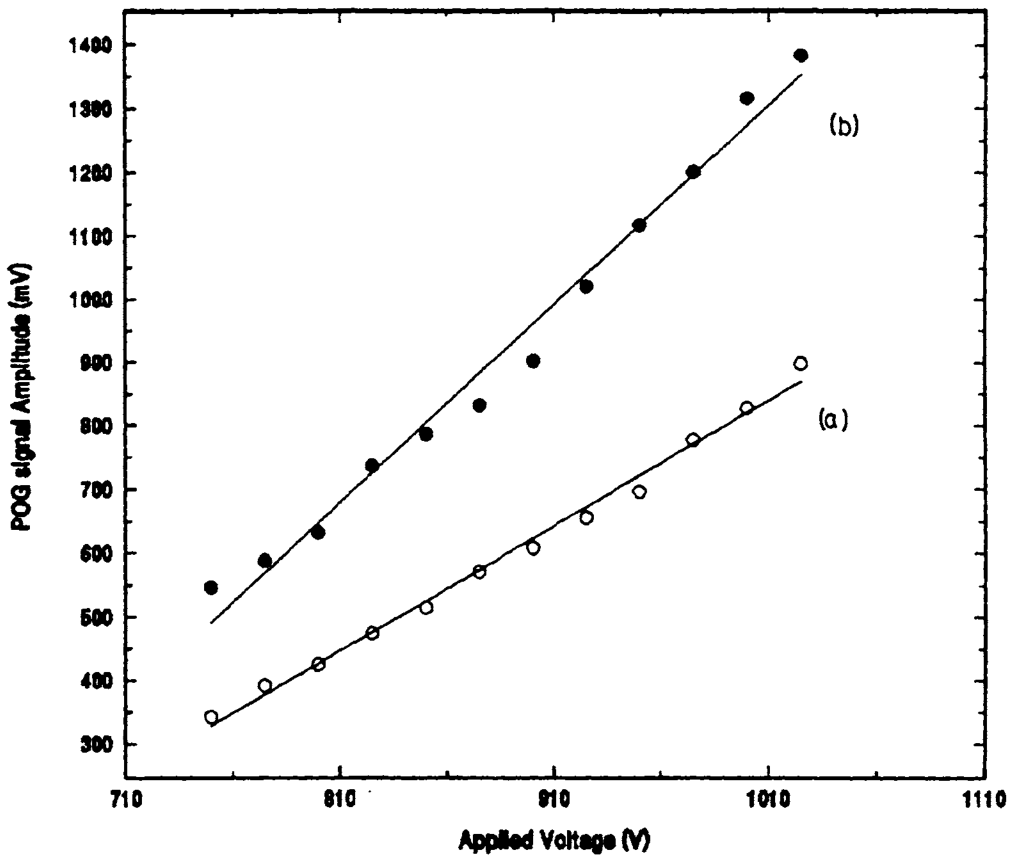


Fig.5.15. Dependence of POG signal on applied voltage, with 532 nm laser pulses. (a) 1 watt, (b) 1.2 watt.

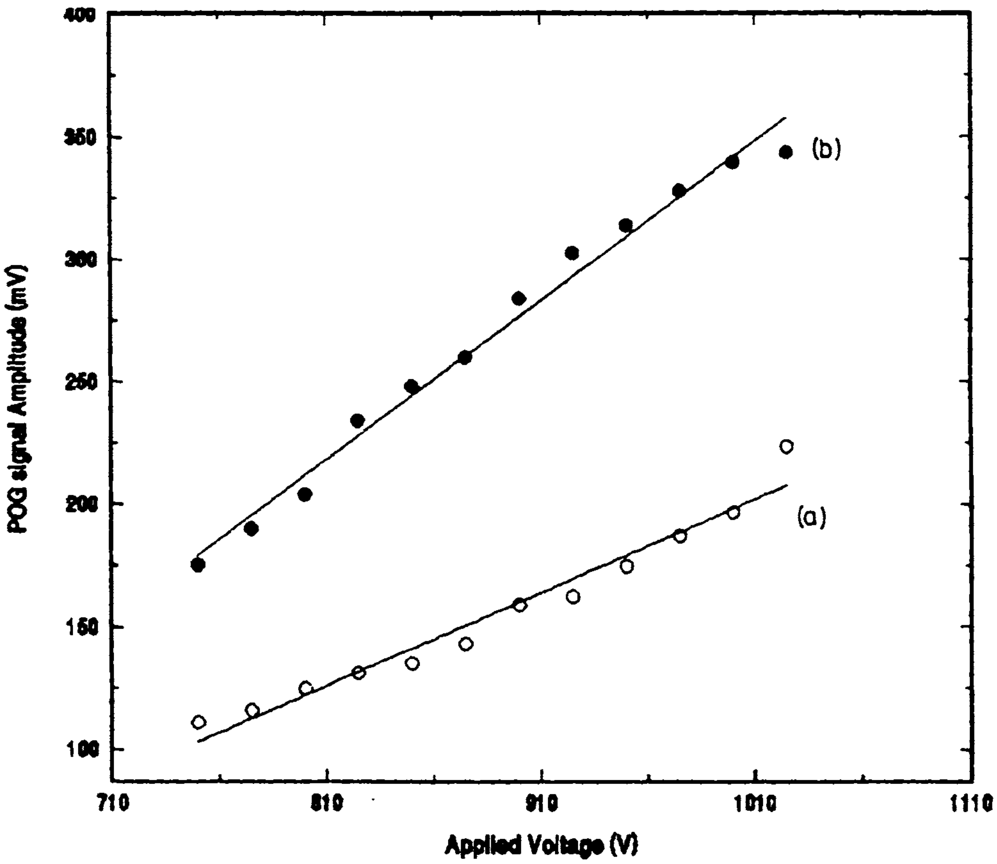


Fig. 5.16. Dependence of POG signal on applied voltage in the reverse biased condition with 532 nm pulses (a) 1 watt, (b) 1.2 watt.

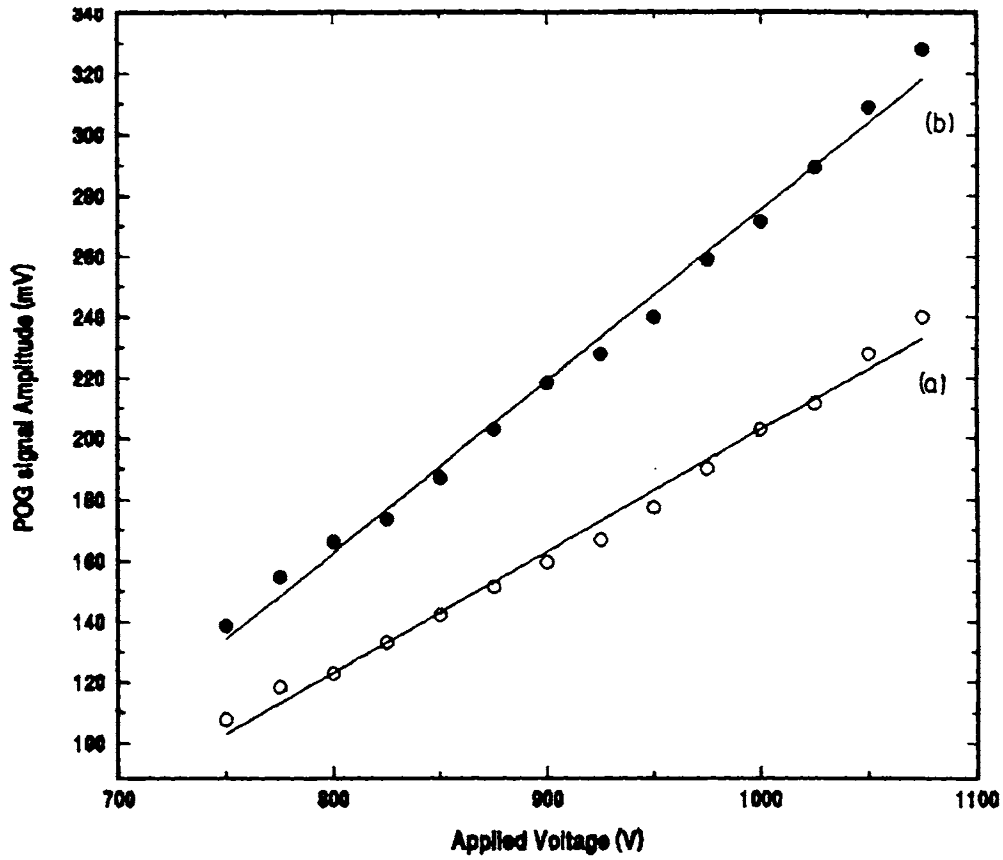


Fig. 5.17. Variation of POG signal strength with respect to applied voltage using 1064 nm (forward bias) (a) 100 mJ, (b) 120 mJ.

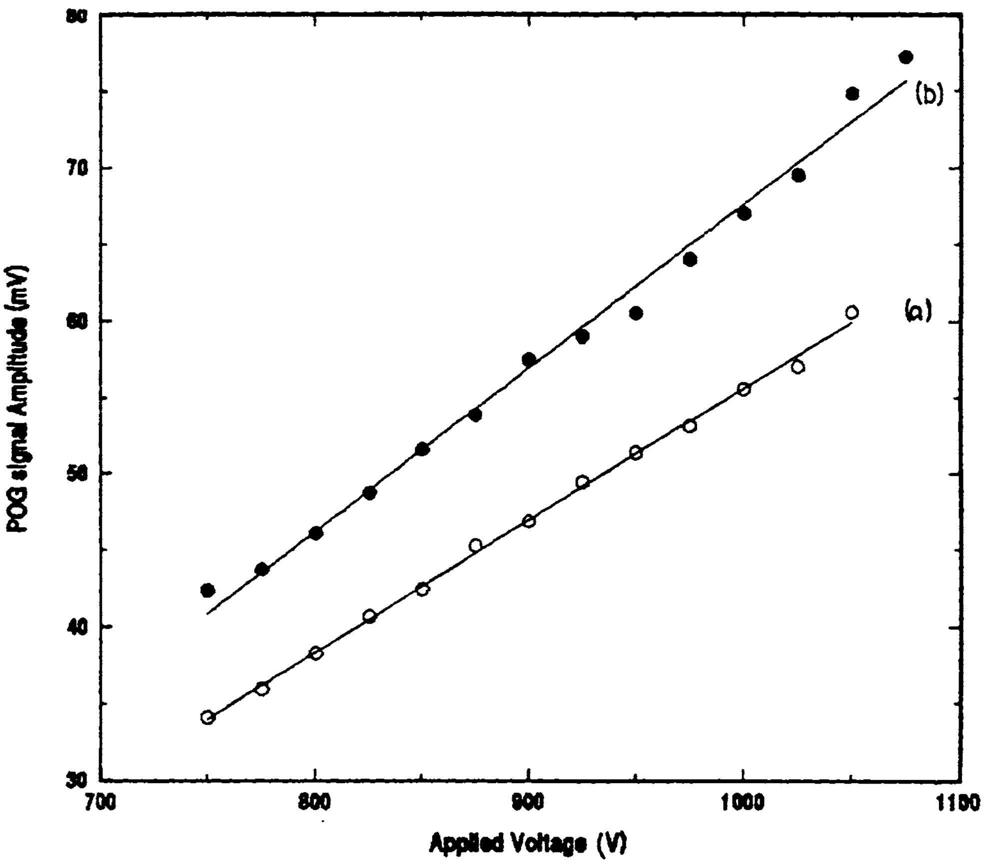


Fig. 5.18. Dependence of POG signal amplitude on the applied voltage in the reverse biased condition using 1064 nm (a) 100 mJ, (b) 120 mJ.

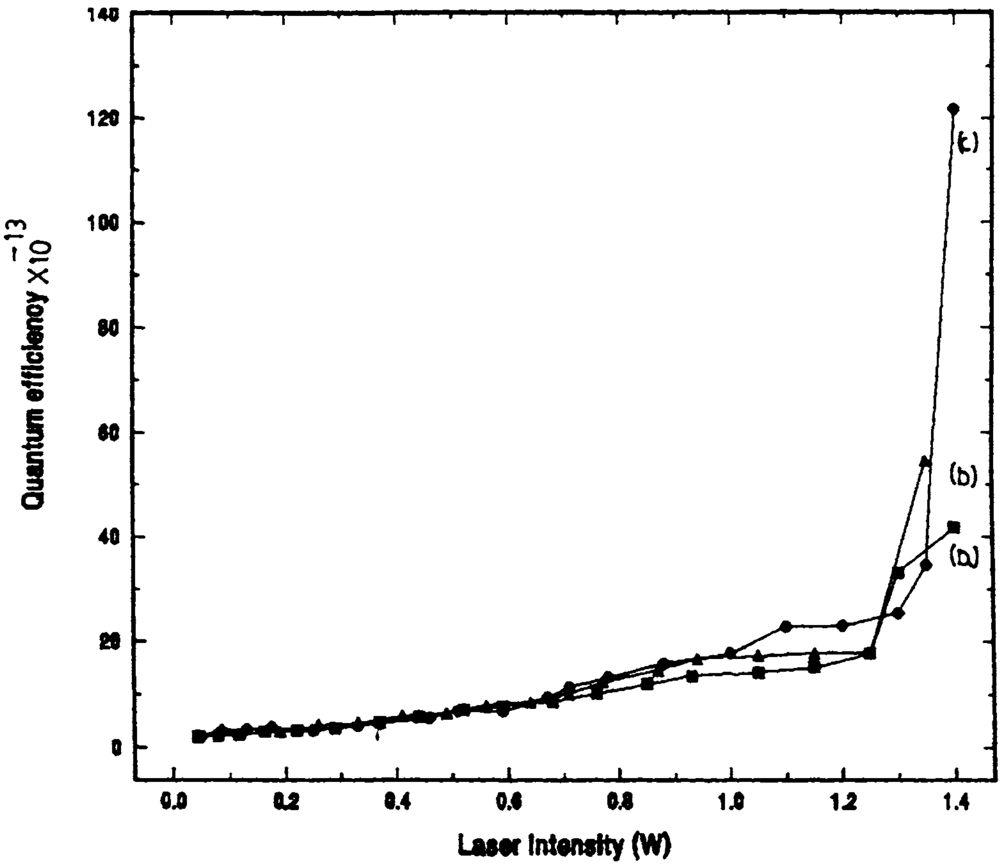


Fig. 5.19. Variation of overall quantum efficiency using platinum with respect to laser intensity in the forward biased condition, (a) 800 V, (b) 900 V and (c) 1000 V.

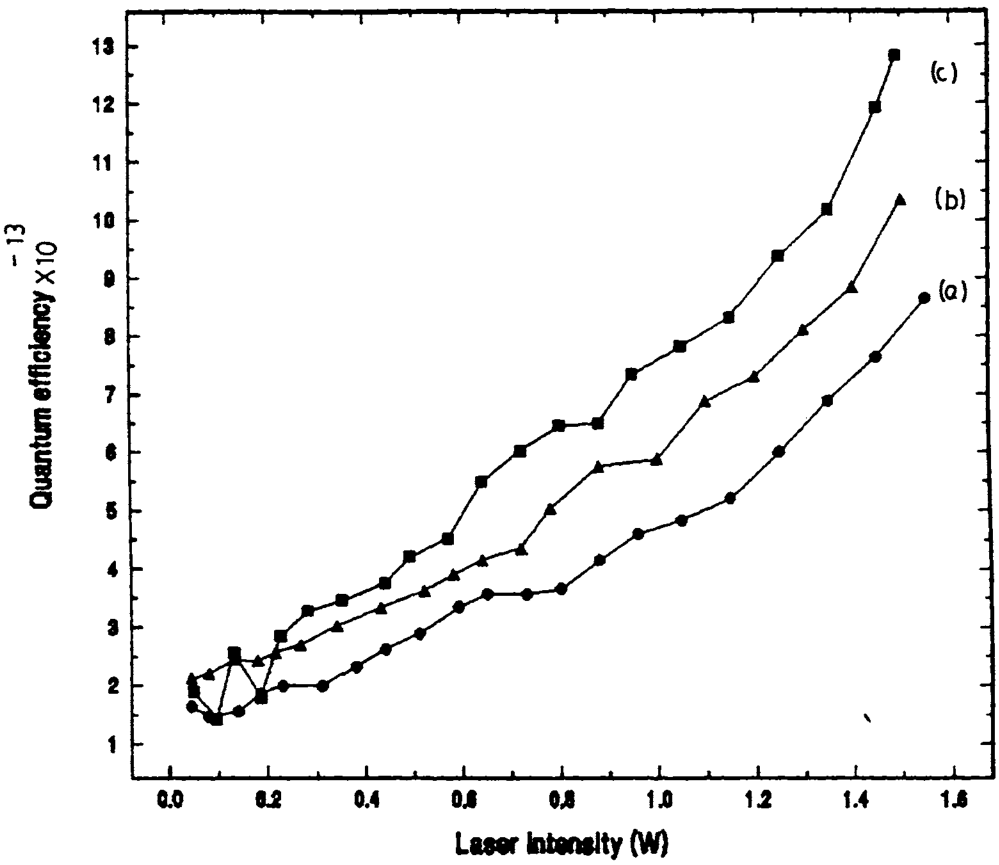


Fig. 5.20. Dependence of overall quantum efficiency using platinum electrode in the reverse biased condition on laser intensity, (a) 800 V, (b) 900 V and (c) 1000 V.

and above the threshold the slope is nearly 5, same as that for 532 nm laser pulses. With 1064 nm (photon energy of ~ 1.16 eV), one can expect a five photon induced photoemission from platinum. The present observation can be due to the heating of the target electrode by infrared laser pulses and electron emission from the tail of the Fermi level can take place [13].

The dependence of POG signal amplitude on discharge voltage has also been noted with platinum. The observation has been made for forward biased and reverse biased conditions with 532 nm and 1064 nm laser pulses (figs.5.15.-5.18.). In all cases a linear dependence is observed. However in the forward biased condition POG signal amplitude is relatively high to the POG signal in reverse biased condition for both 532 nm and 1064 nm. Which indicates the nonavailability of larger number of photoelectrons for transportation in the discharge plasma due to capturing of them by the target electrode in the reverse biased condition.

The dependence of quantum efficiency [12] of platinum on laser intensity is shown in figures 5.19. and 5.20. for forward biased and reverse biased cases. For both cases an increase in quantum efficiency is observed with laser intensity. In both cases the quantum efficiency is relatively higher than that for gold.

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