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Final Report

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Title of Research: Alkali Metal Vapors for Solar Pumped Lasers

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Principal Investigator: Kwang S. Han

Co-Principal Investigator: Nelson Jalufka

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Summary

During the course of this investigation it became apparent that the alkali metal dimers were poor candidates for a direct solar-pumped laser due to the short radiative lifetime of the excited states. After discussions with the technical monitor, the scope of the work was broadened to include any of the diatomic molecules that showed promise as solar-pumped laser candidates.

During the grant period, the work performed consisted of the construction of two (2) dual temperature furnace, set-up and check-out of the experimental apparatus, recording of the broadband absorption of selenium vapor, calculation of the absorption coefficient of selenium vapor as a function of wavelength, recording of the absorption bands of selenium diatomic molecule and initiation of research on the bismuth diatomic molecule.

Dual Temperature Furnace

The details of the dual temperature furnace are shown in figure 1. The upper and lower blocks are made of stainless steel. The slot in the upper block is for the accommodation of the quartz cell containing the selenium. The hole in the lower block accommodates the side arm of the cell which serves as a reservoir. Each block was heated (independently) by four 300 watt cartridge heaters. This arrangement allowed the reservoir to be maintained at a different temperature than that of the cell. This arrangement has the advantage of having the Se_2/Se ratio determined by the cell temperature while the total pressure of selenium vapor is determined by the reservoir temperature. A cell temperature of 760 °C was obtainable.

Experimental Arrangement

The experimental arrangement is shown in figure 2. The 0.5-meter monochromator was equipped with a 1200 lines/mm grating and had a first order dispersion of 1.6 nm/mm. A photomultiplier tube with a GaAs photocathode was placed at the exit slit of the monochromator. This tube has a nearly flat spectral response between 300 nm and 800 nm. The output of the photomultiplier tube was recorded on a strip chart recorder. The xenon lamp was rated at 300 watts and produced a visible spectrum very similar to the solar spectrum between 300 and 800 nm.

Broadband Absorption by Selenium Vapor

Absorption measurements were made at a cell temperature of 700° C and a reservoir temperature of 250° C. Above 700° C the vapor is predominantly Se_2 and hence these conditions correspond to a superheated vapor of density 2.36×10^{15} molecules/cm^3. See Appendix A.

The reduction in intensity (as a function of wavelength) of the radiation from the xenon lamp is given by

$$I = I_0 \exp(-n\sigma x)$$

I_0 = initial intensity at wavelength l,

I = intensity at wavelength l passing through the cell,

n = density of absorbing particle per cm^3.

σ = absorption cross section, cm^2,

x = length of cell, cm.

The recorded spectrum is shown in figure 3. Curve A shows the transition of the cell at room temperature. Curve B shows the transition of the cell at a cell temperature of 700 ^oC and a reservoir temperature of 250 ^oC.

Table I lists the intensity ratio I/I_0 and the absorption cross-section s as a function of wavelength between 300nm and 460 nm. Beyond 460 nm no absorption was detected. The resolution of the monochromator was inadequate to observe individual transition and thus the cross-section represents an average over a broad wavelength range.

ABSORPTION BANDS OF Se_2

Attempts to observe fluorescence from selenium diatomic molecules using an argon laser (visible wavelength) to excite the BO^+_u state were not successful due to the high background pressure in the cell. Since this high density of background gas collisionally deexcite the BO^+_u state, no fluorescence radiation was produced. A second cell was prepared and a small ion pumps was employed to reduce the background pressure in the cell to $< 1.0 \times 10^{-6}$ torr. Using this cell, the absorption measurement were repeated but with a broadband filter placed in front of the xenon lamp. The transmission of the this filter corresponds to the spectral region where $XO^+_g \rightarrow BO^+_g$ absorption is known to occur. The recorded spectrum is shown in figure 5 and clearly shows in the absorption by individual vibrational - vibrational transitions. The position of the $v'' = 0 \rightarrow v' = 0$

transition is marked. Due to the temperature of the cell, a large number of vibrational levels in the XO^+_g ground state will have sufficient population to produce absorption. Therefore, the resulting spectrum is not easy to interpret but it is obvious that even with a fairly narrow portion of the exciting radiation being admitted to the cell, a very large number of vibrational levels (in both states) participate in the absorption. Since the resolution of the monochromator is not sufficient to resolve the rotational levels , the vibrational bands give the appearance of being broadened,

Research on Bismuth

The experimental arrangement for the bismuth research is identical to that used for the selenium except that the half-meter monochromator is replaced by a one-meter focal length monochromator. Preliminary measurements indicate strong vibrational-vibrational band absorption over most of the visible spectrum.

Conclusion

The results obtained so far are insufficient to determine if Se_2 or Bi_2 will be good candidate for a direct solar-pumped laser, while both candidates show strong absorption in the visible portion of the spectrum, the redistribution and subsequent re-radiation of this absorbed energy must be determined. The work initiated under this grant will be continued under NASA grant NAG1-1091. One graduate students, Mr. Seog Sue Jang, was supported by this grant.

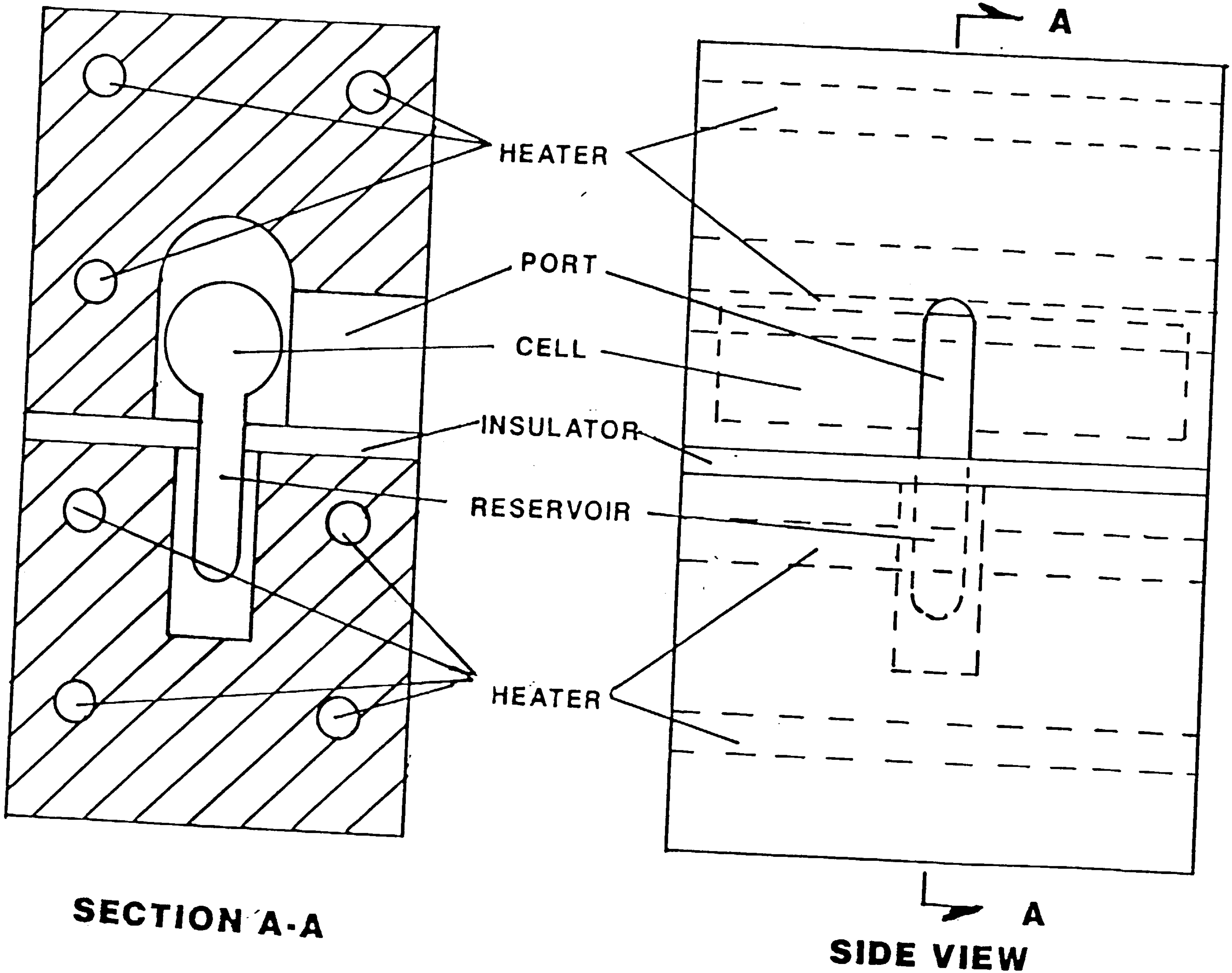
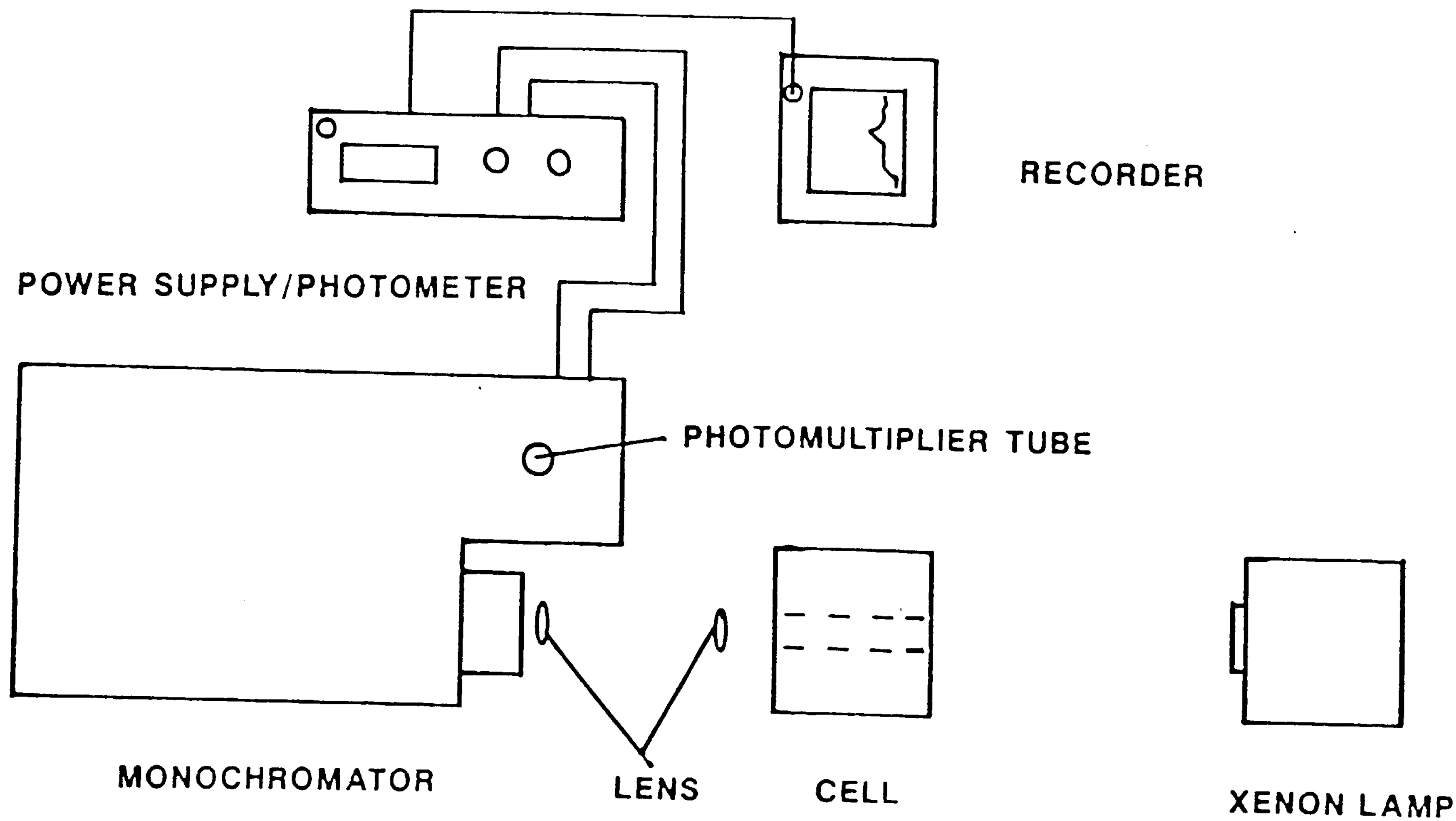

HEATER
PORT
CELL
INSULATOR
RESERVOIR
HEATER
A
A
SECTION A-A
SIDE VIEW

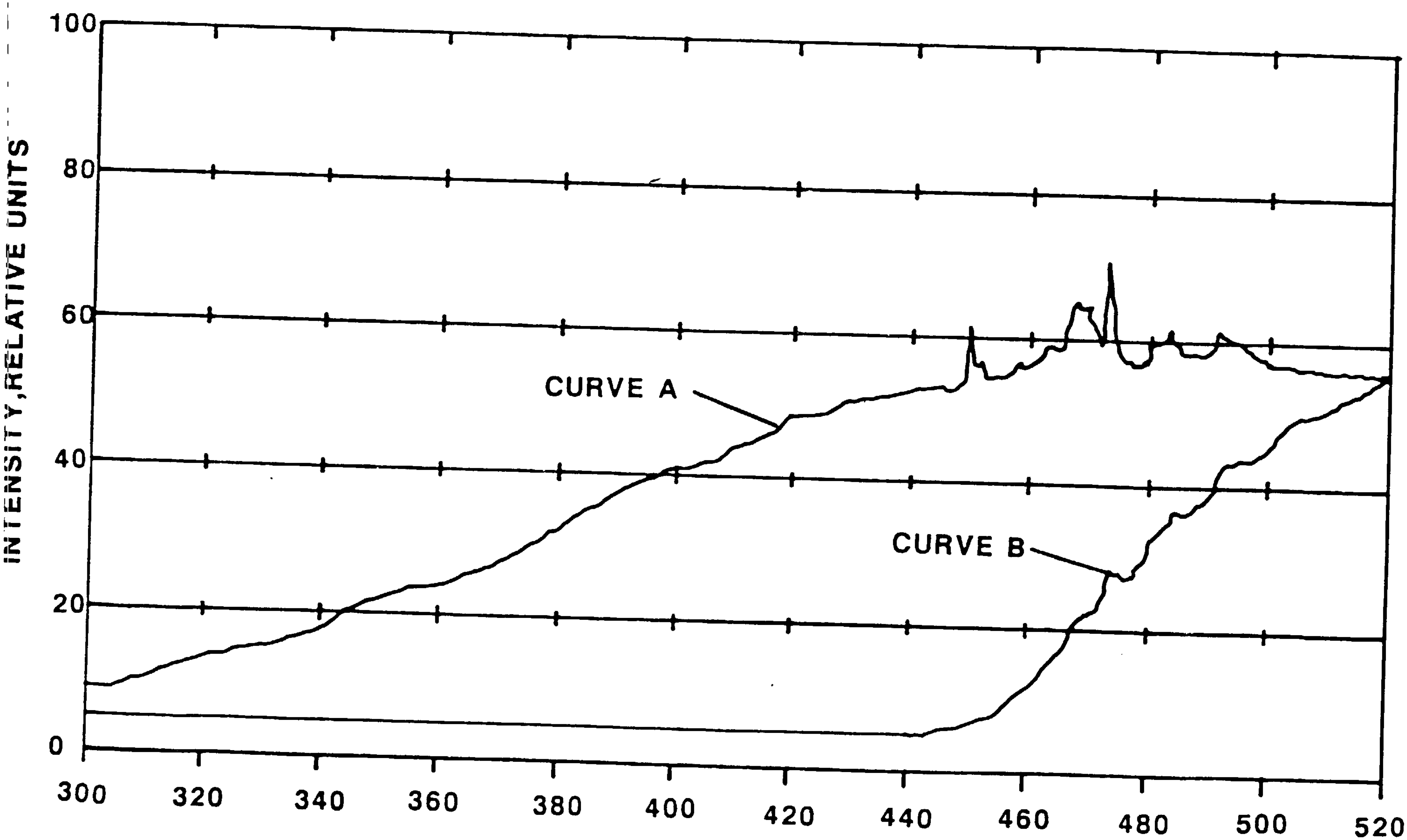
FIGURE 1



RECORDER
POWER SUPPLY/PHOTOMETER
PHOTOMULTIPLIER TUBE
MONOCHROMATOR
LENS
CELL
XENON LAMP

FIGURE 2

ABSORPTION BY SE2 VAPOR



TRANSMISSION OF UV FILTER

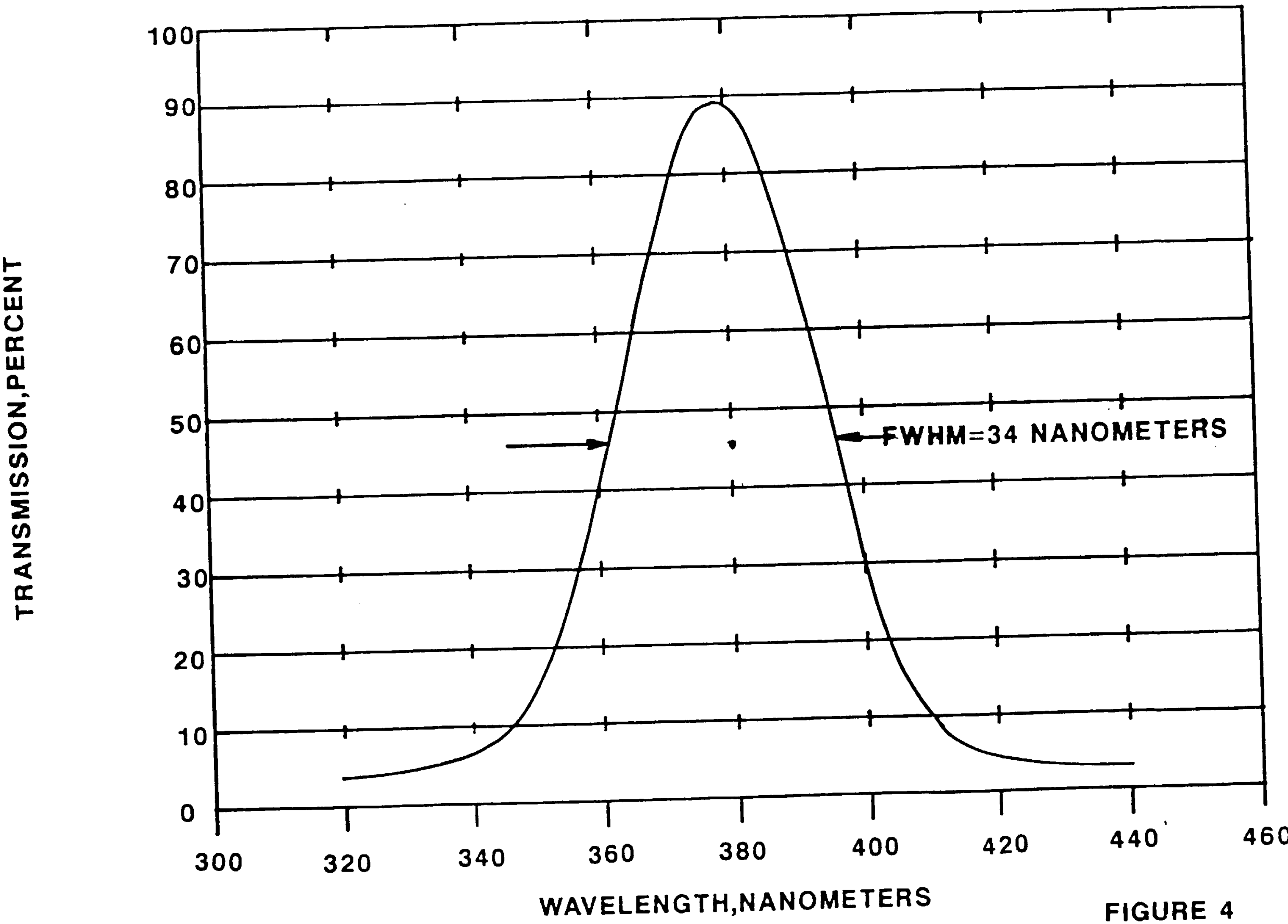
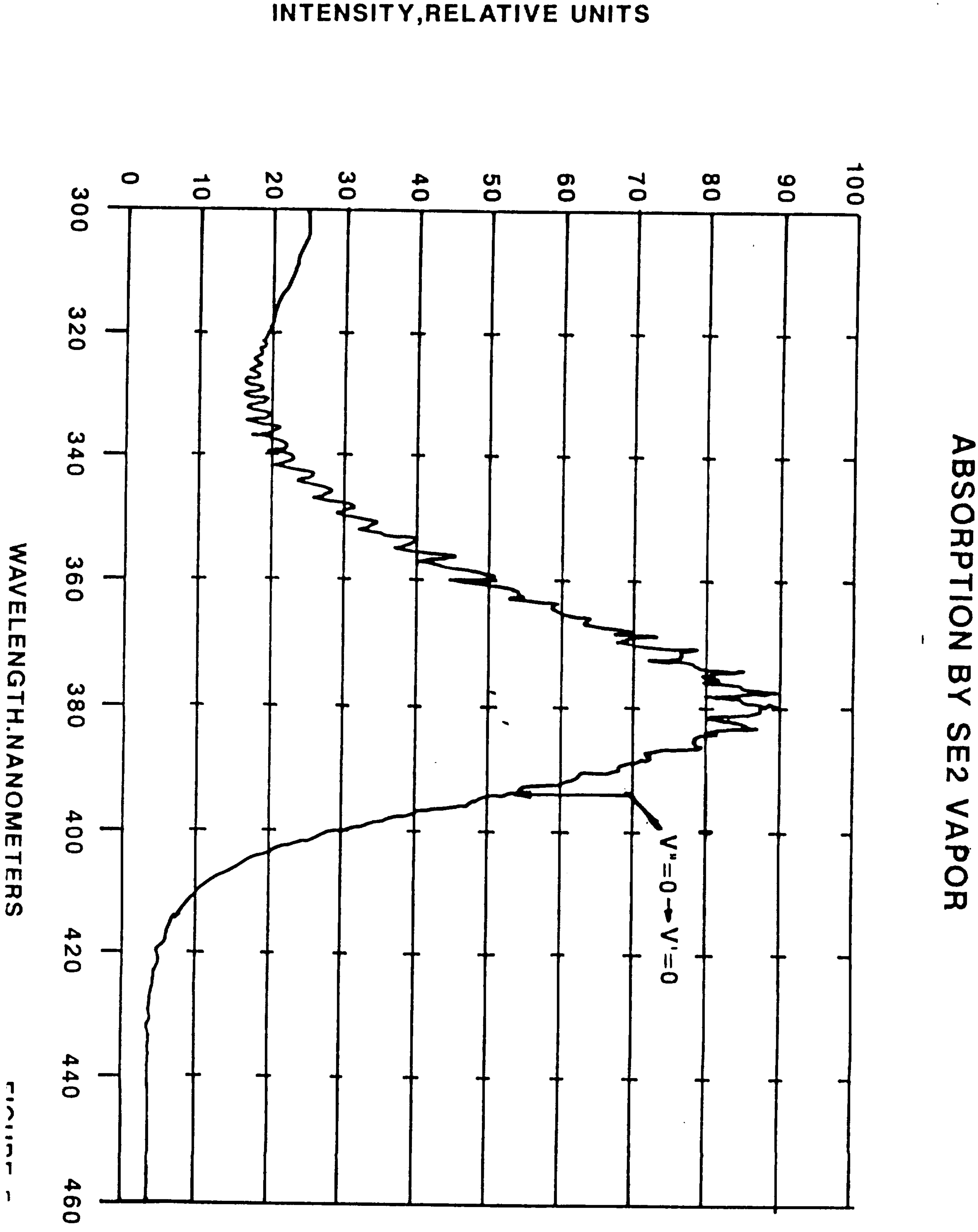


FIGURE 4


ABSORPTION BY SE2 VAPOR
INTENSITY,RELATIVE UNITS
0
10
20
30
40
50
60
70
80
90
100
WAVELENGTH.NANOMETERS
300
320
340
360
380
400
420
440
460
V"=0→V'=0

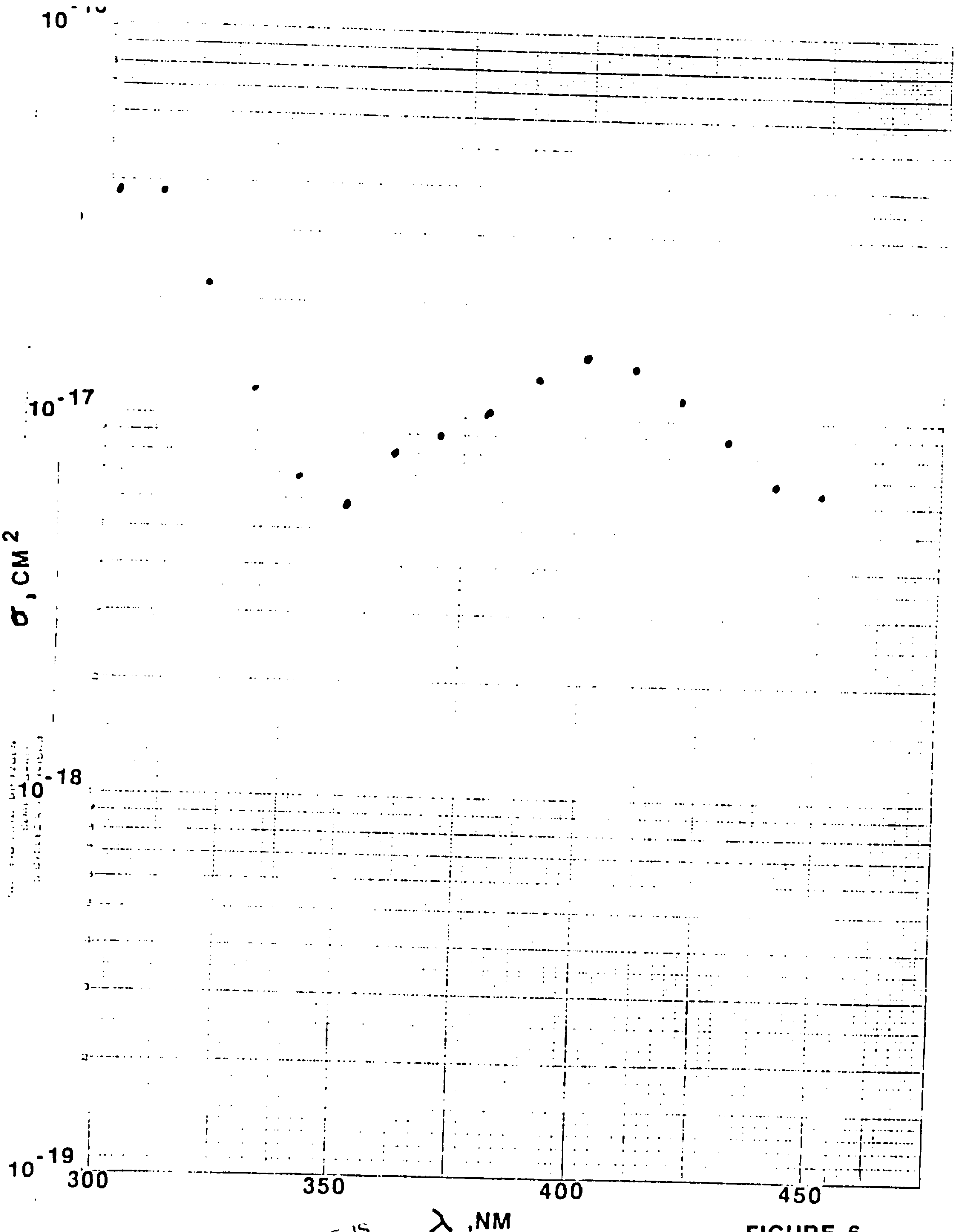


FIGURE 6

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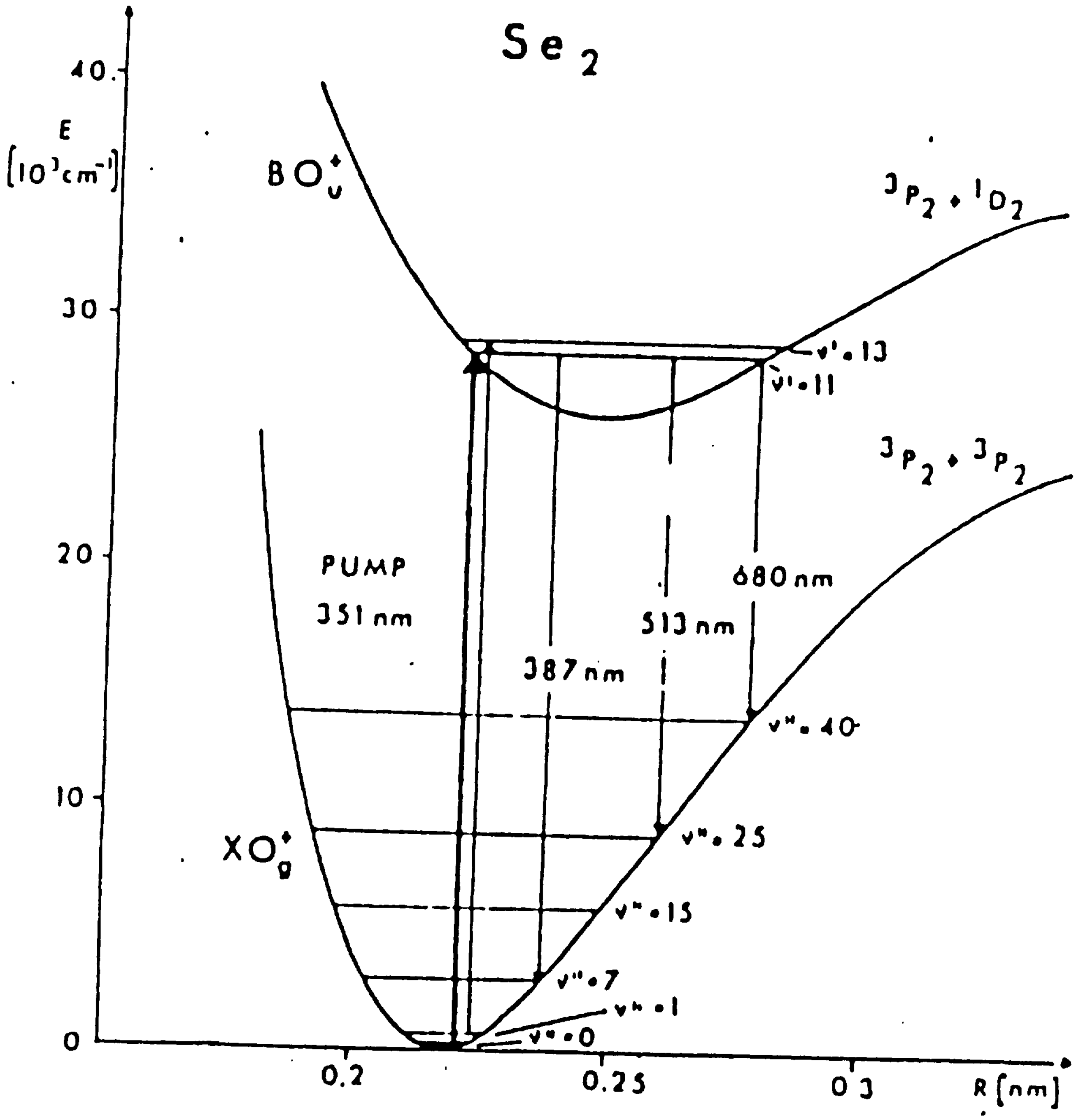

DIATOMIC SELENIUM POTENTIAL ENERGY CURVES

FIGURE 7

APPENDIX A

The density of Se_2 in the cell was determined from the data presented by Nesmeyanov.[1] At 250 ^{0}C the saturated vapor consist predominantly of Se_6 (2.077×10^{-2} Torr) and some Se_2 (4.44×10^{-3} Torr). When this vapor is superheated to 700 ^{0}C, the Se_6 is converted to Se_2 i.e.:

$$Se_6 \rightarrow Se_2$$

The superheated vapor is composed almost entirely of Se_2 molecules so that the total pressure is:

$$3(2.077 \times 10^{-2} \text{ Torr}) + 4.44 \times 10^{-3} \text{ Torr} = 6.674 \times 10^{-2} \text{ Torr}.$$

This corresponds to an Se_2 density of

$$(6.674\text{x}10^{-2})(3.53\text{x}10^{16} \text{ molecules/cm}^3\text{Torr}) = 2.36\text{x}10^{15} \text{ molecules/cm}^3.$$

The variation of the absorption coefficient with wavelength is shown in figure 6. The plot shows two peaks - one at 300-310 nm and a second at about 400 nm. No data could be obtained below 300 nm due to the poor xenon lamp emission in that region. The apparent peak at 300-310 nm is most probably due to the $XO^+_g \rightarrow BO^+_u$ absorption (See figure 7.). The identity of the peak at 400 nm is not clear although it coincides in energy with two photon absorption from XO^+_g to CO^+_u.

1. A. N. Nesmeyanov, Vapor Pressure of the Chemical Elements, Elsevier Publishing Co., Amesterdam, 1963