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13. ABSTRACT (Maximum 200 words)
During the period of June 2003 - June, 2004, A major piece of equipment - picosecond Leopard YAG laser with upgrading existing OPG system, as requested in the proposal was purchased immediately after the award announced. Due to the quality control problem within the Continuum company the laser finally installed in the middle of March 2004. The laser lab is now a well established entity in the study of ultrafast photodynamic processes of optical materials. It functions in both an independent research role for development of the optical materials and a collaboration role. The primary focus of the project this year was on the ultrafast spectroscopic studies of vanadium dioxide thin film as well as heavy metal nanoparticle embedded in melting glass optical materials. It includes:
* Ultrafast passive optical switching derived by enhancement of $\chi^{(3)}$
* Ultrafast photo-induced insulator-metal transition (thermochromic effect)
The first point of focus was started. A large effort was to develop heavy metal nanoparticle doped inorganic glass which has been proved to show enhanced $\chi^{(3)}$ effect. The second point of focus was to study ultrafast phase-transition of VO₂ thin film. This part of work was started right after the new laser installed. With better laser output stability and beam profile we were able to accurately characterize ultrafast time-resolved optical response.

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EXECUTIVE SUMMARY

During the period of June 2003 - June, 2004, the Laser Lab at the University of Puerto Rico-Mayaguez proceeded on schedule following the plan outlined in the original proposal. A major piece of equipment - picosecond Leopard YAG laser with upgrading existing OPG system, as requested in the proposal was purchased immediately after the award announced. The laser was built in July and August 2003 and then shipped to the Campus in August 2003. We received the first installation service in September 2003. However, due to the quality control issue the laser performance was not as good as specified. Particularly, it had a bad beam quality. As negotiation with the Sales of the company, Quantronix-Continuum, the Scientific Sales Engineer, Dr. Noel P. Moore stated in the email: "I had our people in CA send me the final test report so I could see the burn patterns for myself. I was very surprised, they are not at all sufficient. I have left a message for Cliff to ship this laser back to the factory so we may make it right. Let me offer my apologies and restate that my principal goal is to get you a laser that you will be really happy with". The laser was then sent back to the company.

We received the laser back from the company in the middle of January 2004. However, the service engineer working for installation was diagnosed for cancer. We were unable to receive laser installation until the end of February. Finally the installation was done in the middle of March 2004.

The laser lab is now a well established entity in the study of ultrafast photodynamic processes of optical materials. It functions in both an independent research role for development of the optical materials and a collaboration role. The primary focus of the project this year was on the ultrafast spectroscopic studies of vanadium dioxide thin film as well as heavy metal nanoparticle embedded in melting glass optical materials. It includes:

- * Ultrafast passive optical switching derived by enhancement of $\chi^{(3)}$
- * Ultrafast photo-induced insulator-metal transition (thermochromic effect)

The first point of focus was started before the laser installed. A large effort was to develop heavy metal nanoparticle doped inorganic glass which has been proved to show enhanced $\chi^{(3)}$ effect [1-3]. With the purpose of combined effect that the proposed ultrafast phase-transition VO₂ thin film deposited on a substrate of heavy metal nanoparticle-doped glass (HMNDG), we are expecting to observe significant enhanced nonlinearity from this materials. The HMNDG was started with barium phosphate host material. The experiments show that the nanoparticles of silver may controlled at 2 – 10 nm in size which exhibit large surface plasmon enhanced effect. However, used in the second step for thin film deposition it turned out that barium phosphate host was insufficient to sustain the nominal temperature of 500 °C inside the chamber for pulsed-laser-deposition (PLD). The alternative was taken to change the material composition as well as the melting technique, therefore the obtained HMNDG was able to host either silver or gold for PLD purposes. At this point, however, the HMNDG material improvement is still going on. We are expecting to increase the volume content of heavy metal and the uniformity as well.

The second point of focus was to study ultrafast phase-transition of VO₂ thin film. This part of work was started right after the new laser installed. With better laser output stability and beam profile we were able to accurately characterize ultrafast time-resolved optical response. Due to the mixed valence state in nature, at this stage we try to determine the correlation between controlled oxygen flow rate in the PLD process and the VO₂ content in thin films. Since VO₂ has proved to be responsible for the ultrafast nonlinear optical response [4], the monitoring of PLD samples are basically taken by measuring the third-order nonlinearity.

A. ULTRAFAST PASSIVE OPTICAL SWITCHING DERIVED BY ENHANCEMENT OF $\chi^{(3)}$

The conjugate reflectivity of small gold particles was first reported by Ricard et al[5]. At $\lambda=532\text{nm}$, they measured a value of $\chi^{(3)} = 10^{-8}$ esu and a response time of <50 psec. A later paper, by Hache et al.[6] reported the development of a model for third-order nonlinearities in metal particles. The theory outlined in Ref. [6] contains two essential elements to account for the conjugate signal in gold colloids: surface plasmon excitations[7] and a $\chi^{(3)}$ that is due to quantum size effects. At the plasmon resonance large enhancements of the local field inside the particle can be realized. In the quasi-static limit the local field inside a spherical particle, E_L , is related to the applied field, E_0 by:

$$E_L = \frac{3 \varepsilon_d(\omega)}{\varepsilon_m(\omega) + 2 \varepsilon_d(\omega)} E_0 = f(\omega) E_0$$

where $\varepsilon_m = \varepsilon_m' + i \varepsilon_m''$ is the complex dielectric response of the metal, ε_d is the dielectric function of the host material, and $f(\omega)$ is defined as the local-field factor. Local-field enhancements in metal spheres are well known from electromagnetic theory [8]. The denominator in the above expression is the surface-plasmon resonance condition for a sphere. The nonlinear source polarization can be written as:

$$P_{NL}^{(3)} = 3[pf(\omega)^2 |f(\omega)|^2 \chi_m^{(3)}] E_f E_p * E_b = 3\chi^{(3)} E_f E_p * E_b$$

where E_f , E_p and E_b are the electric fields of the three incident beams in the degenerate four-wave mixing (DFWM) experiment and p is the volume fraction of metal particles in the composite material. A significant feature of the model is the strong size dependence of $\chi^{(3)}$, which is proportional to $1/r^3$, where r is the radius of the metal particle. Another possible mechanism to describe the nonlinear response of metal particles is based on nonequilibrium electron heating. Schoenlein et al.[9] measured the change in the reflectivity of a thin gold film, using a pump-probe technique with a 65-fsec pulses. The pump pulse energizes the conduction electrons, resulting in high electronic temperatures while the lattice remains cool. The heating leads to Fermi smearing, which increases the electronic occupancy above the Fermi energy and decreases the occupancy below the Fermi energy. The specific heat of the electron gas is temperature dependent, and at high enough temperatures the change in the occupancy will saturate. The Fermi smearing affects the transition probability of the d-band electrons to the conduction-band energies near the Fermi level, leading to changes in the reflectivity at the surface of the gold film. The hot electron gas cools to the gold lattice through electron-phonon scattering in 2-3 psec. The Fermi smearing or hot-electron contribution has been incorporated by Hache et al. [10] into a model for the nonlinear response of metal-particle composites. The value of $\chi^{(3)}$ due to Fermi smearing is independent of particle size. The surface-plasmon resonance remains an important feature of the observed $\chi^{(3)}$, owing to the enhanced local field described in the above two equations. The results predict that the hot-electron contribution in 5-nm-diameter gold spheres will dominate a quantum size contribution by 2 orders of magnitude.

i) HMNDG sample preparation

The glass batch with the composition of $\text{P}_2\text{O}_5 : \text{Al}_2\text{O}_3 : \text{CaO} : \text{SrO} : \text{BaO} = 58.14 : 8.37 : 8.37 : 8.37 : 16.74$ mol% + AgO or Au₂O Mol. 4% were chosen. The batches were carefully mixed and melted at 1050 °C for 20 minutes (for small quantity). It was then cast rapidly. The obtained sample was further annealed at 450°C for silver and 900 °C for gold. Figure 1 shows the absorption spectra of silver and gold doped HMNDG. It is interesting to note that gold-doped glass is much broader than the silver-doped glass. It may imply that gold-doped sample may be adequate for use in the whole visible region. The obtained silver sample is yellowish while the gold sample is reddish.

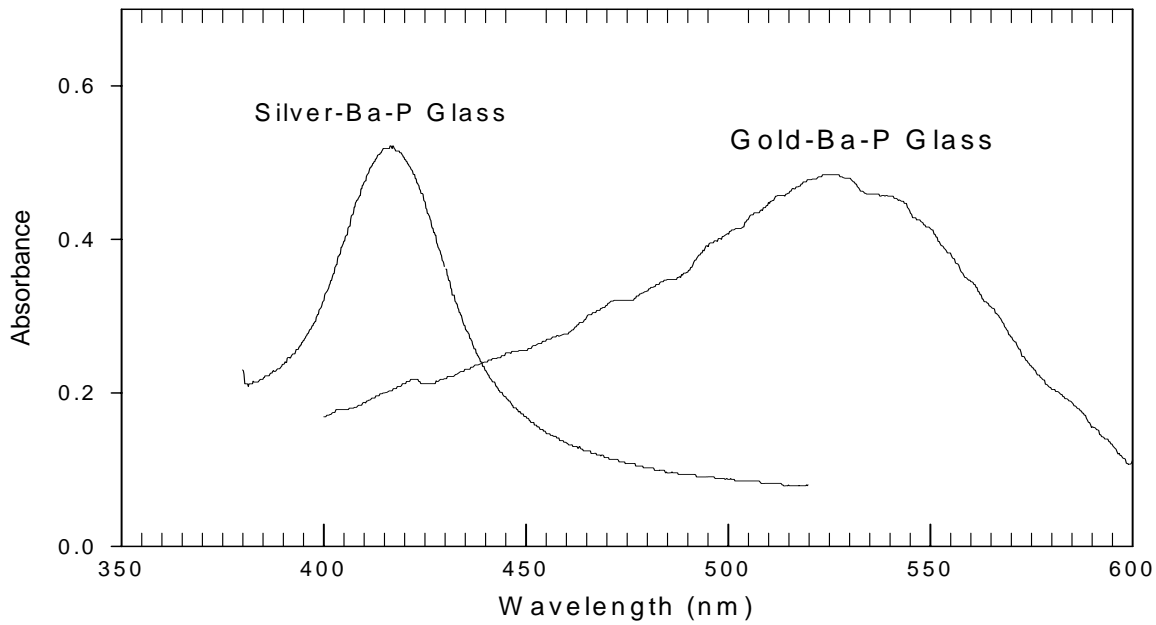


Figure 1. Absorption spectra of HMNDG. Silver-doped glass shows the absorption maximum at 420 nm while gold-doped glass shows the band maximum at 535nm. The latter is even broader.

B. ULTRAFAST PHOTO-INDUCED INSULATOR-METAL TRANSITION (THERMOCHROMIC EFFECT)

Vanadium dioxide is well recognized for its semiconductor-to-metal phase transition at around 68 °C. Recent investigations also show that this phase transition is ultrafast, as fast as the ultrashort laser pulses employed¹. Materials that exhibit ultrafast phase transition caused by thermochromic effect or induced by laser excitation are of central interest at present in optoelectronics and nonlinear optics (NLO) due to their potential application in ultrafast optical switching and passive device applications for optical systems. A number of oxides categorized as Mott insulators exhibit insulator-to-metal transition upon heating to cross the transition point. Most notably, vanadium oxides, such as V_2O_3 ($T_M = 150$ K) and VO_2 ($T_M = 341$ K) show the increase of conductivity by a factor $> 10^4$ across T_M , and this results in a significant change in optical properties. The vanadium dioxide is a rich and widely studied. It is of technological interest as its transition point occurs at the readily accessible temperature of 68 °C which can be easily approached by physical heating, or heat deposition, or by laser excitation at certain level [11,12]. The metallic high-temperature form has a tetragonal rutile structure. Each vanadium ion is situated in the center of an oxygen octahedraon with the parameters $a = b = 4.55$ Å, $c = 2.88$ Å [13,14]. The semiconducting low-temperature form of VO_2 is a monoclinic distortion of the rutile that involves a pairing between two V^{4+} and off-axis displacement of alternate vanadium ions along the rutile c axis. The resultant distortion lowers the symmetry with $a = 5.75$ Å, $b = 5.42$ Å and $c = 5.38$ Å [13,15].

There have been many discussions regarding the laser-induced PT mechanism of VO_2 . Gervais considered the phonon dispersion and the lattice instability at the R point in the Brillouin zone [16]. Gupta et al calculated the band structure and explained using charge density waves [17]. The strong electron-phonon interaction was reported by Raman experiment [18] and X-ray as well [19]. In contrast, by measuring reflectivity

versus time delay Cavalleri et al [11,20], recently observed that the time scale of PT depends on the excitation level, which may occur in subpicoseconds to nanoseconds. In result they concluded that the structural transition may not be thermally initiated. In this paper, we show the optical and photoluminescence properties of the optical quality PLD-VO₂ thin film. And it is the first time, to our knowledge, to report the extremely large polarizability observed in VO₂ and the excited-state related lattice dynamical processes.

i) PLD - VO₂ FILM PREPARATION

VO₂ films were grown by reactive PLD on fused quartz substrates and MgO substrate as well. A metallic vanadium target was used, which was rotated during laser ablation to avoid crater formation. A Lambda Physik 110 excimer (KrF, 248 nm emission) laser operating at a repetition rate of 10 pps and the average fluence on the target surface at ~ 14 J/cm² was used for ablation. Background pressure in the chamber was 10⁻⁶ Torr. Argon and oxygen gases were admitted into the chamber by separate controllers on O₂ /Ar flow rates. The O₂ flow was controlled to be within 0.3 - 1.5 sccm (standard cubic centimeter per minute). Total deposition time for each of the samples was 40 minutes and the film thickness is estimated to be between 01 ~ 0.5 μm for each sample.

After film growth, all samples appeared smooth. The sample grown with the highest oxygen flow shows a brownish and blue color, while with moderate flow rate the sample is bronze and the sample with highest oxygen supplied looks dark grey. The samples were not further treated after deposition. Examination with an optical microscope showed micron-sized particles apparently due to target ejecta, but their number was relatively small, considering the fact that a metallic target was employed for the PLD process. X-ray diffraction scans of all samples show a very broad diffraction peak under $2\theta = 25^\circ$, corresponding to amorphous material. But since the substrate is amorphous this is not conclusive. In addition, a single sharp reflection, close to the (011) peak for monoclinic VO₂, which is by far the most intense peak for this material (see, for example, PDF file 82-0661). It is likely that there is amorphous material in these samples, along with crystalline VO₂.

The thermochromic effect, such as resistivity, optical transmission and optical reflectivity versus temperature was examined on all samples. Reversible structural change with typical hysteresis curves at TP of 68 - 70EC was observed, but the change in percentage of resistivity and transmission was not as great as observed in VO₂ single crystal. It indicates that the existing PLD-VO₂ thin film has relatively loose structure.

ii) OPTICAL AND ELECTRIC PROPERTIES

Optical absorption

Optical absorption of all samples obtained was measured in order to reveal the effect of oxygen flow rate on growth condition. In general, vanadium may coexist in different valence states, such as V⁰(metallic), V²⁺, V³⁺, V⁴⁺ and V⁵⁺ depending on the oxygen supplied during the film grow process. For very limited amount of oxygen supplied, the absorption curve only shows a shoulder at ~320 nm, corresponding to the cut-of-edge of quartz silica (CT band). Most vanadium deposited appears to be in metallic state, and the obtained sample shows no thermochromic effect. With the oxygen flow rate increased to certain amount, the thin films obtained contain more VO₂ as verified by X-ray diffraction measurement. The films look like blue-brownish and exhibit better thermochromic effect. However the oxygen deficiency must be still kept during film growth in order to suppress the content of V⁵⁺. In this case some V⁴⁺ might be present in the film as interstitial ions. Their optical absorption shows double bands at 340 nm and 420 nm respectively. Presumably they are associated with Jahn-Teller splitting of the *d* orbital of V⁴⁺ ions in distorted octahedral site with Δ estimated to be 26,300 cm⁻¹. When further to increase the oxygen supply, the VO₂ content decreases and poor thermochromic effect was observed.

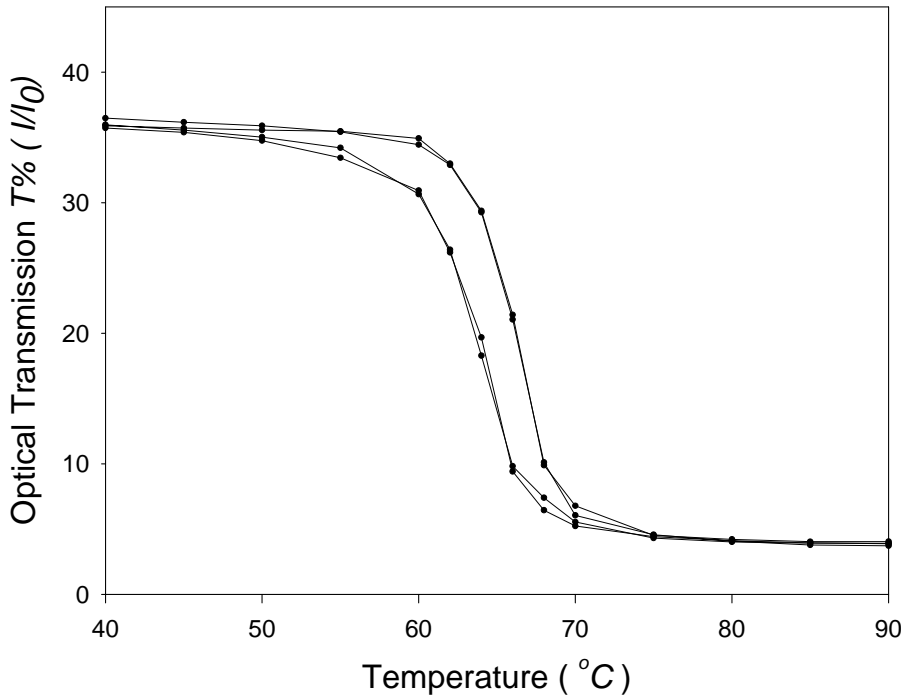


Figure 2. Change in optical transmission at 1.25 μm due to semiconductor-to-metallic phase transition at $\sim 68^\circ\text{C}$ in PLD- VO_2 film deposited on MgO substrate.

Change in optical transmission due to PT

The changing in optical transmission was observed by using thermally induced PT as well as optically induced PT. Fig. 2 shows the change in T% at various temperatures for VO_2 deposited on MgO substrate sample. At room temperature the transmission is 36% at 1.25 μm . The transmission starts to decrease at $\sim 60^\circ\text{C}$ when the sample temperature increases. When the temperature passes the PT point of 68°C , it reaches the minimum value of 4% at $\sim 70^\circ\text{C}$. It remains constant when temperature further increases. On the reverse cooling process, the transmission gradually increases when passing through the PT point. It exhibits a typical hysteresis of optical transmission around 68°C PT point while vanadium dioxide shows a change of metallic tetragonal rutile structure to/from a monoclinic phase.

The phase change can also be induced by optical excitation as it will be shown in the next paragraph. The change in optical transmission due to optical pump was observed using pump-probe technique. In the experiment, a picosecond-YAG laser operated at 532nm was used as optical pump source while a CW He-Ne laser at 632nm as well as a delayed 532nm pulses were used for light transmission measurement. The transmitted 632.8nm light received by a PMT was gated by a Boxcar Averager. The pump pulse of 30 psec width at 532 nm entered the sample at a fixed time. The probe beam entered the sample at the time ranging from -50 psec to $+100$ psec with respect to the pump pulse. The reduction was found to be laser power dependent. With the pump pulse fluence at $40 \text{ mJ}/\text{cm}^2$ the transmission at 532 nm was reduced by a maximum of 15% while changing to $20 \text{ mJ}/\text{cm}^2$ the transmission reduction became 10%.

The reason to use a gated signal is due to time dependent PT observable upon laser

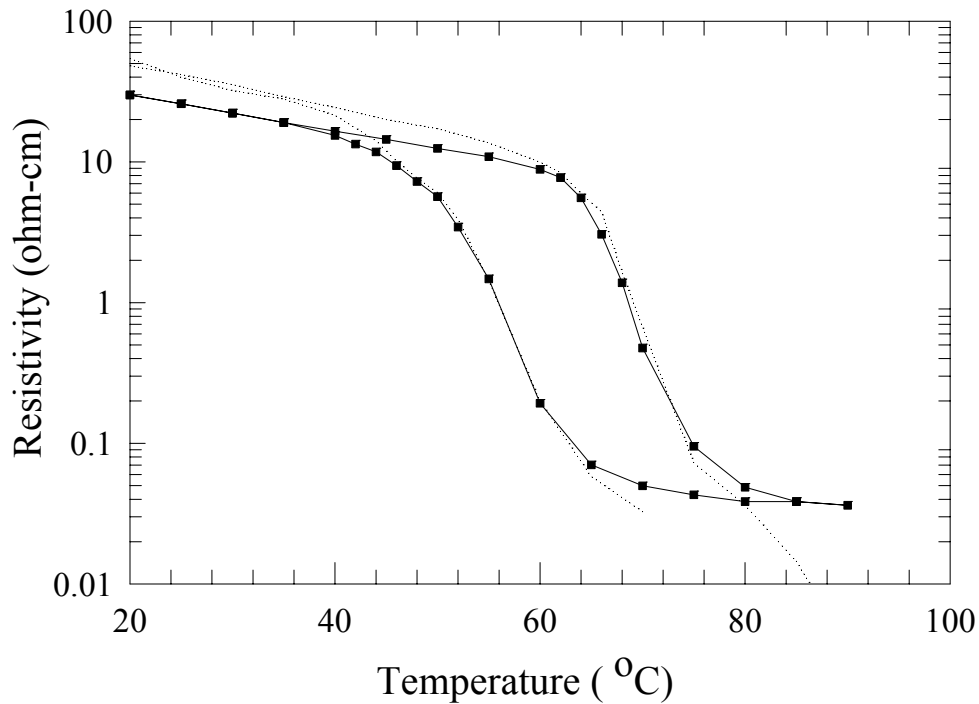


Figure 3. Change in resistivity due to semiconductor-to-metallic phase transition in PLD-VO₂ films deposited on fused quartz substrates. It clearly shows the hysteresis around 68EC. The solid line represents the measurement taken by setting current at 2 μ A while the dotted line represents the measurement taken at 0.25 μ A.

excitation which will be depicted in DFWM experiment. The maximum change of DFWM signal was found to be \sim 200ps delayed, and it decays to \sim 30% at 8 ns delay time.

Change in electric resistivity due to PT

The thermochromic effect due to PT in electric resistivity was measured using a four-point probe. The samples used in the measurement are PLD-VO₂ thin film deposited on quartz surface with thickness ranging from 1000 to 1500 Å. Resistivity was measured while heating and cooling the samples from 25°C to 120°C. As shown in Fig.3 a reversible structural change with typical hysteresis curves at PT point of 68 - 70EC was observed. On the left side it represents the material in an insulator state while on the right side it represents the material in a metallic state. The insulator state possesses resistivity at tens ohm-cm whereas the metal shows a much smaller resistivity at \sim 3 \times 10⁻² ohm-cm. Yet the measurement indicates that the existing PLD-VO₂ thin films have relatively loose structure, as mentioned above, which exhibit relatively insignificant thermochromic effect due to PT.

iii) OPTICALLY INDUCED PHASE TRANSITION IDENTIFIED BY EXCITED STATE DYNAMICS IN TRANSIENT HOLOGRAPHY

Transient holography

A backward configuration of DFWM arrangement was used to measure the nonlinear properties of the HMNDG samples. The ultrafast dynamic holography produced by cross-over of two coherent ultrashort laser pulses has been used as a powerful tool in identifying excited state dynamics. Fig.4 shows the experimental

setup using a $Y_3Al_5O_{12}:Nd^{3+}$ (Nd:YAG) laser pumped optical parametric generator (OPG) as the excitation source in a DFWM configuration. Output wavelength of the laser system was tunable in a range of 400 nm – 650 nm when the third harmonic of YAG was employed, or operated at 532 nm with a TEM₀₀ mode when the second harmonic of frequency doubling was used. Pulse width of the laser output was typically between 25 – 30 psec. The laser beam was then split into three beams, and spatially overlapped in the sample in a conventional backward propagating degenerate four-wave mixing geometry. As shown in Fig.3, the two pump pulses (equally divided by a 50% beam splitter (BS)) with one pulse controlled by a sophisticated optical delay line of 15 fsec accuracy were s-polarized, and they cross inside the sample to generate a sinusoid interference pattern. The third laser beam with the power less than 10% of the laser output was selected by another BS and served as a probe beam.

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The probe beam was aligned in a direction anti-parallel to, and phase conjugated to one of the pump beam. It was partially diffracted, giving rise to a signal pulse which identified as the fourth beam. All the pulses were co-linearly polarized in a (ssss) geometry. The scattered signal beam was monitored by a Pico-Joule meter. The optical delay line used for a pump beam was to control its arriving time relative to the principal pulse while the other delay line controls the probe delay relative to the principal pump pulse. The “zero delay” was defined in such a way that the temporal and spatial overlap of the three beams at zero delay time will in principle result in maximum instantaneous response signal when a CS₂ standard is used. The signal observed at the delay time greater than zero is defined as post-zero signal. When the holographic pattern produced by the interference of the two equally divided crossing pulse with crossing angle of 2θ and each with light intensity I , the transient grating due to the light intensity modulation is formed by $I=2I[I+\cos(qx)]$ for polarizations (ss). In the bright area of the interference pattern the light-matter interaction results in the population of excited state, which consequently causes the change in polarizability of excited state versus ground state. The grating vector is $\mathbf{q}=\pm(\mathbf{k}_A - \mathbf{k}_B)$ confined in the film, where $\mathbf{k}_A, \mathbf{k}_B$ stand for the wavevector of pulse A and B respectively. In this experiment a degenerate-four-wave-mixing (DFWM) technique with a common backward configuration was used for study of transient holography. The pump energy during this experiment was set relatively lower in most cases in order for preventing the sample from damage. Therefore any possible change in transmission induced is negligible. The signal obtained is associated with the change in index of reflection as $\Delta n=[\Delta n_{10}(I)\cos kx]_{t=0}+[\Delta n_{20}e^{-t/\tau}\cos kx]_{t>0}+\Delta n_{30}\cos(kx)(1-\cos\omega t)$, where k, τ and ω are the grating wavevector, excited state relaxation time and phonon frequency, respectively. The coefficients $\Delta n_{10}, \Delta n_{20}$ and Δn_{30} are the pump intensity dependent amplitudes of refractive index changes arising from different interactions. The first term is responsible for the instantaneous (t=0) contribution to the scattered signal, arising from the $\chi^{(3)}$ including resonant enhancements. The second term allows for the scattering of the probe at time delay longer than the autocorrelation width of the three beams and arises from changes in polarizability due to excited state population. The last term account for changes in the index of refraction due to laser induced acoustic waves.

Mechanism responsible for observed transient holography

Figure 5 represents a time-resolved, transient holography which plotted as diffracted signal versus the time delay for a PLD-VO₂ film deposited on a fused quartz substrate. It clearly shows the excited state dynamic process of VO₂ film, which was induced by optical excitation. In the inset a sharp peak signal at zero probe delay represent an intrinsic optical response which is associated with the third-order susceptibility of the material. The signa post-zero delay represents the transient grating produced by laser excitation of VO₂ film coupled to its excited states¹¹. The signal intensity is proportional to the square of the change in polarizability which is associated with

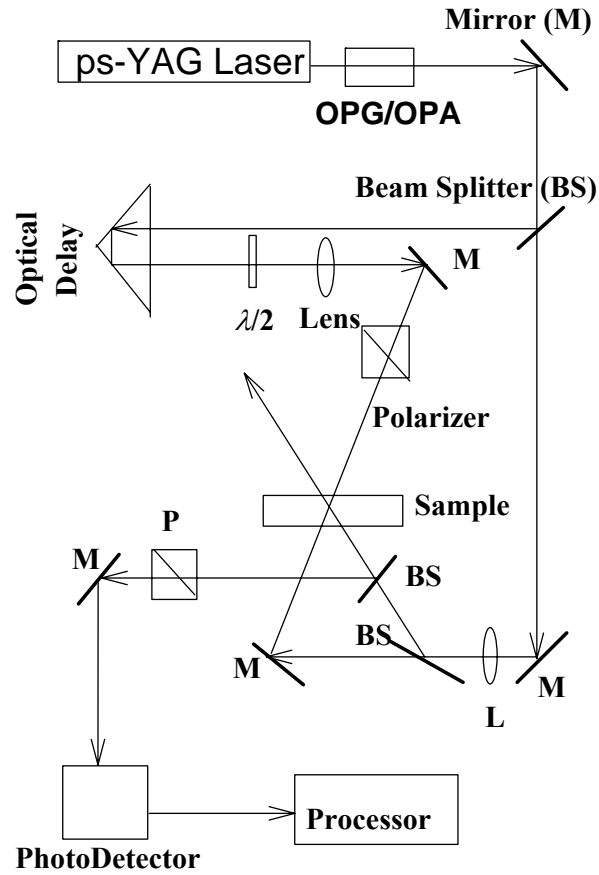


Figure 4. Block diagram for transient holography experiment using DFWM technique. The ultrafast laser pulse through BS and optical delay line serves as a probe while the other two pulse beams divided through BS serve as pump pulses. The fourth wave, signal pulse produced by diffraction of probe due to formed transient holography through the grating created inside the sample.

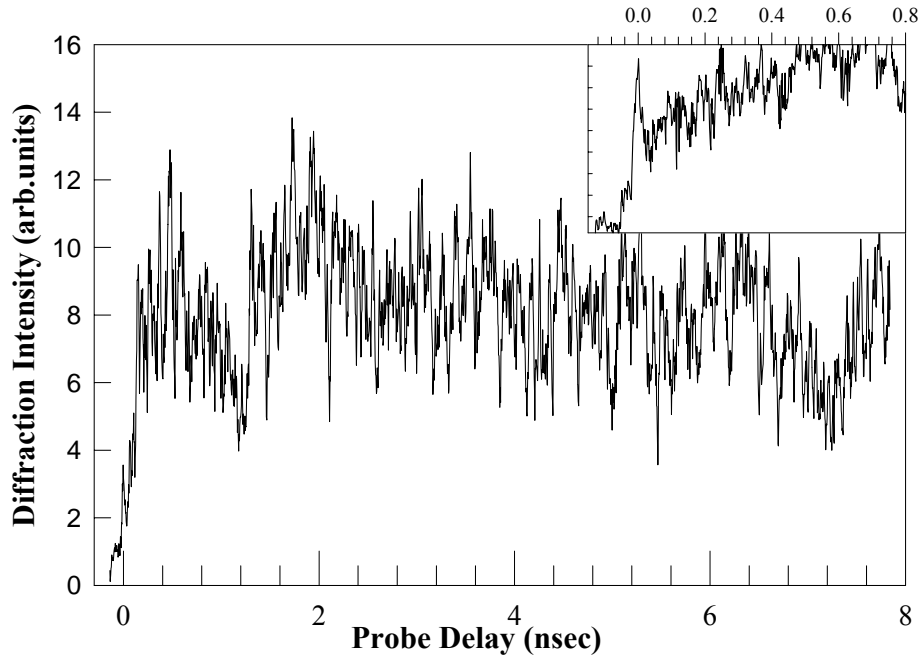


Figure 5. Transient holography of PLD-VO₂ film deposited on fused quartz substrate. It clearly shows a time-resolved dynamic process of excited state in the thin film induced by optical pumping. In the inset a sharp peak signal at zero probe delay is associated with the third-order susceptibility. Post-zero delay signal builds up reaching the maximum at ~ 0.7 nsec. The signal decays at varying decay rate depending on the pump energy. The decay curve shown in the figure was obtained with pump fluence at 10 mJ/cm^2 .

the transient lattice displacement caused by laser excitation^{12, 13}. In Fig.4, the signal reaches its maximum value at ~ 0.6 nsec of the probe delay when the pump energy was between $0.5 - 3 \text{ mJ/cm}^2$, the fluence for each pump beam. The time was reduced significantly when pump fluence was higher than 8 mJ/cm^2 . As show in the main frame of figure 5, where the pump fluence was 0.5 mJ/cm^2 for each beam, the grating signal overwhelms the sharp instantaneous component. There is a distinguishable signal damping down at 1.2 nsec forming a dip in the profile. This observation was reproducible in over hundreds measurements as long as the pump fluence was kept moderately low. It was also excluded from acoustic phonon contribution by theoretical analysis as well as by experimental verification. Since the observed post-zero signal (proportional to the square of the change in polarizability) is even 3.2 times greater than the intrinsic response at zero-delay the lattice displacement is estimated to be quite a significant. As the lattice parameters briefed in the introduction, a large change of lattice constant along c-axis was found to be associated with the phase transition from semiconductor to metallic state. Therefore it suggests that the laser induced phase transition is the cause giving rise to such an intense post-zero grating signal.

It is worth to note that a special precaution must be taken in the experiment when the higher pump energy was employed. Since the film can also be ablated by extremely strong laser illumination the grating signal intensity may decrease with time over a long period for taking data. The signal would eventually vanish at the time when the film was totally gone. In this circumstance, a small clear spot with no film left could be seen. Furthermore, the experiment was also conducted for the sample heated over 68°C . As manifested, there

was no grating signal observed because the VO₂ film was already in a metallic phase before laser excitation. Therefore all these observations propose that the observed transient holography in the VO₂ thin film is associated with the excited state dynamical process which essentially causes the structural change, or so-called optically induced-PT.

Another feature of the transient holography is that the grating signal shows a distinguishable signal damping down at 1.2 nsec forming a dip in the profile, then re-grows up again. This observation was persistent and reproducible as long as the pump fluence was kept moderately low. When higher pump energy was employed, the post-zero signal grows rapidly and the time for grating signal to reach the maximum decreases. It is believed that the observed dip may be assigned to an unknown middle state bridging the semiconductor and metallic phase.

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LIST OF PUBLICATIONS

Peer reviewed Journals:

- 1) H. Liu, O. Vasquez, V.R. Santiago, L. Diaz, F.E. Fernandez, "Host excitation induced red emission from Pr³⁺ in strontium barium niobate thin film", **J. Lumin.** **108 (2004) 37-41**.
- 2) H. Liu, O. Vasquez, V.R. Santiago, L. Diaz, F.E. Fernandez, "Excited state dynamics and insulator-to-metallic phase transition of VO₂ thin film", **J. Lumin.** **108 (2004) 233-238**.
- 3) H. Liu, O. Vasquez, V.R. Santiago, L. Díaz, F.E. Fernandez, "Semiconductor-to-metallic Phase Transition of VO₂ by Laser Excitation", Journal of Electronic Materials, 2004, scheduled in October issue..

Peer reviewed conference proceedings:

- 1) H. Liu, O. Vasquez, V.R. Santiago, L. Díaz, F.E. Fernandez, "Novel PLD-VO₂ thin film for ultrafast applications" 2004 TMS Annual Meeting, Charlotte, NC, March 14-17, 2004.
- 2) H. Liu, O. Vazquez, L. Diaz, S. Avanesyan, L.F. Fonseca, Z. S. Weisz, L.Liu, L. Xu, F. Gan, "Enhanced ultrafast nonlinear optical response in Si/SiO₂ Nanocomposite" Proc.10th Intern.Conf.Composite/Nano Engineering, Ed.by David Hui, New Orleans, LA, Pg.425, 2003.
- 3) H. Liu, K.Q. Ni, J. Seguel, D. Bollman, "Time domain analysis for measuring ultrafast optical response", Proc.10th Intern.Conf.Composite/Nano Engineering, Ed.by David Hui, New Orleans, LA, Pg.427, 2003.
- 4) H. Liu, K.Q. Ni, J. Seguel, D. Bollman, "Time-resolved ultrafast molecular nonlinear optical response", Proc. Shanghai Intern. Symp. Nonlinear Sci. Appl. (SNSA). Nov.9-13, 2003.

LIST OF INVENTION

None

LIST OF EQUIPMENTS PURCHASED BY THE GRANT

The major piece of equipment granted is a Leopard D-10 Continuum cavity dumped ultrastable amplified picosecond Nd:YAG laser with dye saturable absorber system. The selling price was quoted as of total \$99,440, plus shipping charge. A bargaining and negotiation were taking place with the company. As a existing company customer, they finally offer a waive of all charges for upgrading OPG which was initially planned in the project. In addition, the company offered a discount of \$5,400 toward the purchasing of laser itself. Therefore we were able to upgrade the existing OPG system to a computer controlled system - company recommended version with software provided for free of charge.

No	Item	Manufactory	Qt	Price (\$)
1	Leopard D-10 Cavity Dumped ultrastable amplified picosecond laser with dye saturable absorber <20 ps pulse duration	Continuum	1	79,000.00
2	Second, third and fourth harmonic generators for use with Leopard laser.	Continuum	1	8,400.00
3	Upgrade existing OPG	Continuum	1	-
4	OPG Crystals	Continuum	1	-
5	Existing Customer Discount	Continuum	1	-5,400.00
6	KW4 series spin coater, hotplate UV cure and parts	Chemmat Technology	1	8,516.00
7	74-UV/VIS Preconfigured USB2000 Fluorescence Spectrometer for OPG output testing	Ocean optics	1	2,893.00
8	Desktop Dimension and laptop computers for Upgraded OPG and Fluorescence Spectrometer	Dell, CDW	2	5,830.00
	TOTAL			99,239.00