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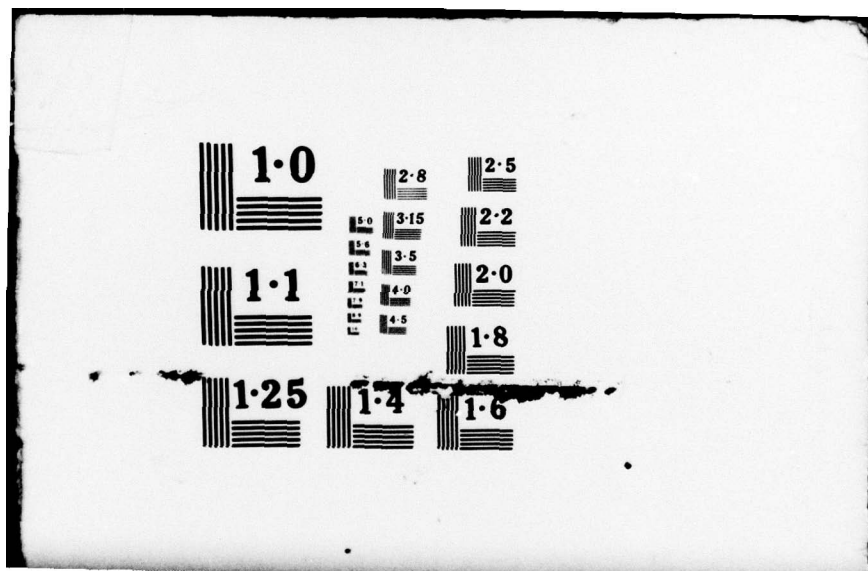
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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>During the period of the grant advances were made in the theory of nonlocal optics (spatial dispersion phenomena) in solids including prediction of new phenomena in transient optics: precursors, transient reflectivity, altered signal velocity. Surface related optical properties including lateral displacement, selective total internal reflection were investigated. All the above relate to exciton-mediated optical properties of insulators and semiconductors. New optical phenomena related to morphic effects (stress related) were determined. New electronic models for properties of the A-15 compounds were proposed with (over) |                       |                                                                           |

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quantitative agreement with experiment. A random stacking model for structure of amorphous tetrahedral semiconductors was proposed and tested. A two phonon Raman Scattering feature in diamond was identified as an overtone. Two books ( ) and 47 papers were published.

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INVESTIGATION INTO SELECTED PROBLEMS IN SOLID STATE PHYSICS

FINAL REPORT

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8 NOVEMBER 1978

U. S. ARMY RESEARCH OFFICE

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## 1. FOREWORD

During the period 1 November 1974 - 31 August 1978 our group was supported in part under grants DAHCO4-75-G-0052 and DAAG29-78-G0021.

Major advances were the following. We initiated and exploited the theory of a new branch of spectroscopy, namely, transient optical properties (reflectivity, ATR, and related). We showed that this new branch of spectroscopy has the potential for exploring surface structure including surface irregularities of solids as well as the light matter interaction and elementary excitations in solids. We initiated new work on structural models for amorphous tetrahedral semiconductors. The random stacking model has the merit of being largely analytical.

We initiated new work on a new variety of total internal reflectivity phenomena by which non-local and surface irregularities can be investigated.

We exploited many manifestations of symmetry for optical properties of crystals including stress induced changes in scattering (morphic effects). We demonstrated that a two-phonon Raman anomaly observed in diamond may be interpreted as a simple overtone and not necessarily a collective (bound) state. We continued the investigations into new optical properties of solids due to non-locality -- our predicted new resonance Brillouin Scattering anomalies have been verified experimentally. We investigated a new electronic model for A-15 compounds by which anomalous properties can be explained.

2. TABLE OF CONTENTS (Not given - report under 10 pages)

3. APPENDICES (None)

#### 4. REPORT

The major lines of our research supported under these grants heavily emphasize the theory of optical properties of crystals. In particular we have been engaged in systematically exploiting novel and measurable effects due to spatial dispersion of solids. These novel effects are in the domain of non-local optics. Owing to the wave vector dependence of the dielectric response function entirely new modes of energy transport, and elementary excitations become available. For example, exciton polaritons now carry electromagnetic energy in solid and surface modes. Our theoretical work has exploited all varieties of physical phenomena connected with the existence of these new elementary excitations, and means of coupling to them and detailed properties connected with energy transport.

We discovered some years ago that an entirely new type of Resonance Brillouin Scattering phenomenon (involving interaction between the exciton polaritons and acoustic phonons) could occur. This was dramatically confirmed in 1977 after many years of intense experimental searching by outstanding research groups at the Ecole Polytechnique (France), Max-Planck-Institute (Germany), IBM Labs and elsewhere. They have also confirmed the existence of new channels and new scattering effects.

We have predicted other new and dramatic effects related to transient optics including novel precursors, changes in signal velocity. These can be related not only to novel energy transport but also to the existence of new surface modes of surface excitations.

A second major line of our work concerns symmetry effects in solids. We have systematically exploited the existence of symmetry and predicted and analysed, many types of phenomena in solids. These include polarization - depolarization experiments in light scattering. Also strain induced and changed scattering has been predicted. In addition we have applied group theory and symmetry in entirely novel context to phase transitions.

Another significant line of our work concerns investigation of properties of the superconductors of A-15 structure including  $V_3Si$  and  $Nb_3Sn$ . We have developed a new electronic model which has been very successful in explaining a wide variety of important experimental observations. The crux of our model is that a symmetry determined property underlies the physics.

Another line of our work concerns investigation of structural models and properties of amorphous tetrahedrally coordinated media. We have developed and exploited a new random stacking model which offers promise insofar as a considerable part of the analysis can be carried out analytically. Most of the other models used in the field of amorphous media have required extensive numerical calculation only, whereas, our model permits part of the work to be done analytically and enables us to gain physical insight.

A number of other shorter projects have been completed in related areas including study of the overtone spectrum of diamond (harmonic approximation) which appears to explain and observe light scattering feature, without the necessity of invoking a bound state. A study of lattice dynamics in  $Cu_2O$  was carried out.

A list of 47 publications is appended to this report. These were supported by ARO (in part) during 1974-1978.

Publications 1974 - 1978 under ARO Sponsorship

(A) Books Published 1974-77

1. "Theory of Crystal Space Groups and Infra-Red and Raman Lattices Processes of Insulating Crystals", Handbuch der Physik, Vol 25/2b by J.L. Birman (Springer-Verlag 1974)
2. "Theory of Light Scattering in Condensed Matter" (Plenum Press 1976) co-edited by J.L. Birman, V.M. Agranovich and B. Bendow.

(B) Articles Published/Submitted 1974-77

1. "Calculation on 2-Phonon Bound States in Diamond and Germanium", C.H. Wu and J.L. Birman, J. Phys. Chem. Solids, Vol. 36, 305-308, Pergamon(1974)
2. "Electrodynamics of Bounded Spatially Dispersive Media: The Additional Boundary Conditions", C.S. Ting, M.J. Frankel and J.L. Birman, Solid State Comm. 17, 1285 (1975).
3. "Theory of the Arrest of Elastic Softening in Superconducting  $\beta$ -W Compounds", C.S. Ting and J.L. Birman, Phys. Rev. B 12, 1093 (1975).
4. "Clebsch-Gordan Coefficients for Crystal Space Groups" by R. Berenson and J.L. Birman, J. of Math. Phys. Vol. 16, 227 (Feb. 1975).
5. "Clebsch-Gordan Coefficients for  $*X O *X$  in Diamond  $O_h^7$ -Fd3m and Rocksalt  $O_h^5$ -Fm3-", R. Berenson, I. Itzkan and J.L. Birman, J. of Math. Phys. Vol. 16, 236 (Feb. 1975).
6. "Theory of New Transients and Optical Phenomena in Spatially Dispersive Media" by M.J. Frankel and J.L. Birman, Proc. of Int'l. Conf. on OPTICAL PROPERTIES OF HIGHLY TRANSPARENT SOLIDS; ed. Bendow and Mitra, (Feb. 1975).

7. "Predicted New Electromagnetic Precursors in Dispersive Media", J.L. Birman and M.J. Frankel, Optics Comm. 13, 303 (1975).
8. "The Electron-Hole Drop and the Impurity-Induced Semiconductor-Metal Transition" by G. Mahler and J.L. Birman, Solid State Comm. 17, 1381 (1975).
9. "Properties of the Electron-Hole Drop in n-doped Ge and Si" by G. Mahler and J.L. Birman, Phys. Rev. B, 13, 3221 (1975).
10. "Determination of the Band-Gap Decrease in Doped Ge and Si From Drop Properties" by G. Mahler and J.L. Birman, Phys. Rev. B, 13, 3661 (1976).
11. "Electrodynamics of Non-Local Bounded Dielectrics by M.J. Frankel and J.L. Birman, Phys. Rev. B 13, 2587 (1976).
12. "Two-Phonon Spectrum in Diamond" by R. Tubino and J.L. Birman, Phys. Rev. Lett. 35, 670 (1975).
13. "Raman Intensities in Covalent Crystals: A Bond-Polarizability Approach by R. Tubino and L. Piseri, Phys. Rev. B, 11, 5145 (1975).
14. "Raman Intensities in Covalent Crystals: Two-Phonon Raman Spectrum in Diamond" by R. Tubino and J.L. Birman (published in Proc. Int'l. Conf. Light Scattering, Brazil, Flammariion (1975).
15. "Symmetry of the Raman Scattering Tensor Including 'Morphic' Effects by R. Berenson and J.L. Birman (published in Proc. Int'l. Conf. on Light Scattering, Brazil, Flammariion (1975).

16. "Symmetry Effects in Resonance Scattering" by J.L. Birman,  
(published in "Light Scattering in Condensed Matter",  
eds. B. Bendow, V.M. Agranovich and J.L. Birman)  
(Plenum 1976).
17. "Transient Optical Response of a Spatially Dispersive  
Medium" by M.J. Frankel and J.L. Birman, Phys. Rev.  
A15, 2000 (1977).
18. "Effective Hamiltonian and Clebsch-Gordan Coefficients  
in Crystals" by J.L. Birman, T.K. Lee and R. Berenson,  
Phys. Rev. B, 14, 318, (1976)
19. "Are Superconductivity and Ferroelectricity Mutually  
Compatible?" by J.L. Birman, Journal of "Ferroelectrics"  
16, 171 (1977).
20. "A New Subgroup Approach to the Thermodynamic (Landau)  
Theory of Continuous Phase Transitions in Structurally  
Complex Crystals" by A. Agyei and J.L. Birman, Journal  
of "Ferroelectrics" 16, 167 (1977).
21. "Applications of Crystal Clebsch-Gordan Coefficients,"  
R. Berenson and J.L. Birman, now published in the  
Proceedings of the 5th Int'l. Colloquium on Group Theory  
Methods in Physics-Montreal (1976). (Ed. R. Sharp, Springer-  
Verlag)
22. "A Group Theoretic Description of the Magnetic Phase  
Transitions in the  $AB_2O_4$ -Type Spinel," A.K. Agyei and  
J.L. Birman, now published in the Proceedings of the  
5th Int'l Colloquium on Group Theory Methods in Physics-  
Montreal (1976)

23. "Theory of Two-Phonon Raman Spectrum of Diamond",  
R. Tubino and J.L. Birman, Phys. Rev. B15, 5843 (1977).
24. "Transition-Active  $k=0$  Representations and the Micro-  
scopic Description of Phase Transitions", A.K. Agyei  
and J.L. Birman, published in Physica Status  
Solidi (b) 80, 509 (1977).
25. "A New Group Theoretical Approach to Cell-Preserving  
Phase Transitions in Crystals", A.K. Agyei and  
J.L. Birman, published in Physica Status Solidi (b),  
82, 565 (1977).
26. "Random Stacking Model Applied to Tetrahedrally Bonded  
Amorphous Semiconductors: The Scattering Intensity",  
F. Yonezawa and J.L. Birman; Phys. Rev. B16, 2707 (1977).
27. "A Random Stacking Model for Tetrahedrally Coordinated  
Amorphous Semiconductors", F. Yonezawa and J.L. Birman,  
J. Phys. C10, L277 (1977).
28. "New Algorithms for the Molien Function", M. Jaric and  
J.L. Birman, J. Math. Phys. 18, 1456 (1977).
29. "Calculation of the Molien Generating Function for  
Invariants of Space Groups", M. Jaric and J.L. Birman,  
J. Math. Phys., 18, 1459 (1977).
30. "Group Theory of Phase Transitions in A-15 ( $O_h^3$ -Pm3n)  
Structure", M. Jaric and J.L. Birman, Phys. Rev. B16,  
2564 (1977).
31. "X-Point Model for Magnetic Susceptibility of A-15  
Compounds", C.S. Ting and J.L. Birman, Physics Letters,  
64A, 87 (1977).

32. "Scattering Tensors and Clebsch-Gordan Coefficients in Crystals: Brillouin and Morphotropic Effects", R. Berenson  
(submitted for publication)
33. "Lattice Dynamics of  $\text{Cu}_2\text{O}$ ", R. Cavaleiro and J.L. Birman  
published in Int. Conf. Lattice Dynamics, Paris,  
(Flammarion 1978) ed. M. Balkanski.
34. "Landau Theory of Symmetry Change in A-15 Compounds"  
M. Jaric and J.L. Birman, Phys. Rev. B16, 2564 (1977).
35. "New Three-Dimensional  $\vec{k} \cdot \vec{p}$  Model for the Electronic  
Structure of A-15 Compounds" T.K. Lee, J.L. Birman and  
S.J. Williamson, Phys. Rev. Lett. 39, 839 (1977).
36. "Applications of a New Three-Dimensional  $\vec{k} \cdot \vec{p}$  Model for the  
A-15 Crystals for the Properties of  $\text{V}_3\text{Si}$ " (with T.K. Lee  
and S.J. Williamson) to appear in Physics Letters A, 64 (1977).
37. "Theory of Transient Behavior of Electromagnetic Fields in a  
Spatially Dispersive Dielectric and a New Approach to the  
Theory of Precursors" (with M.J. Frankel and D.N. Pattanayak).  
Proc. of Conference on Coherence and Quantum Optics, Rochester  
June 1977). Eds. L. Mandel and E. Wolf, Rochester, N.Y.
38. "Group Theory of the Landau-Thermodynamic Theory of Continuous  
Phase Transitions in Crystals" - Proc. of Vith Int'l. Colloq.  
on Group Theoretical Methods in Physics - Tubingen, July 1977.  
ed. P. Kramer, Vieweg (1977-78).
39. "Molien Function and Calculation of Invariant Polynomials  
for Space Groups" - Proc. of Vith Int'l Coll. on Group  
Theoretical Methods in Physics - Tubingen, July 1977. ed. P.  
Kramer, Vieweg (1977-78). (with M. Jaric)
40. "Theory of Electron-Hole Plasma in Highly Excited Si and Ge"  
G. Mahler and J.L. Birman, Phys. Rev. B16, 1552 (1977).
41. "X-Point Model for Magnetic Susceptibility of A-15 Compounds"  
C.S. Ting and J.L. Birman, Phys. Lett. 64A, 87 (1977).
42. "A New Three-Dimensional  $\vec{k} \cdot \vec{p}$  Model for the Electronic Structure  
of A-15 Compounds and Application to Anomalous Properties  
of  $\text{V}_3\text{Si}$  and  $\text{Nb}_3\text{Sn}$  in the Cubic Phase, T.K. Lee and J.L.  
Birman: Phys. Rev. B17, 4931 (1978).

43. "Boundary Value Formulation and Integro-differential Equations for Time Dependent Electromagnetic Scattering Theory, D.N. Pattanayak and J.L. Birman. Optics Comm. 25, 281 (1978).
44. "Electrical Quadrupole Sum Rules in Solids, C.H. Wu, G. Mahler and J.L. Birman Phys. Rev. B. (Oct. 1978) in press.
45. "Proof of Sommerfeld's Conjecture that Wave Front Travels with Vacuum Velocity of Light in any Material Medium" D.N. Pattanayak and J.L. Birman. Optics Comm. (submitted).
46. "Renormalization Group Theory of Structural Phase Transitions in A-15:  $\text{Pm3n-O}_h^3$ " M.V. Jaric and Joseph L. Birman, to be published in Proc. of the Group Theoretical Meeting, Austin, Texas (Springer-Verlag 1979).
47. "A Surface Wave Dispersion Relation for Non-Local Media" D.N. Pattanayak and J.L. Birman. Solid State Comm. (ed. A.A. Maradudin) in press (1978).