HISTORICAL PERSPECTIVES ON LASERS IN DENTISTRY

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INTRODUCTION

As will be shown today, it should not follow that extended seniority, often senescence, should warrant the acclaim of a keynote address. There is an impression of a part of the mouth, that I have kept on my desk for some years to show what happens when you do not examine in detail the entire mouth. This impression shows a squamous carcinoma of the posterior aspect of

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the gum which I missed, because I did not examine closely the posterior oral cavity. So, this bit of an impression serves as a reminder to me of how unlearned I truly am.

To assist you in developing some perspectives on the history of lasers in dentistry, the following material will be presented:

- 1963 - "I Start on the Teeth" from the Laser Laboratory Medical Center, University of Cincinnati.

- 1987 - "Laser Dentistry" (my current review) from the Laser Laboratory, Medical Center, University of Cincinnati.

- 1991 - "NonSurgical Medicine" (my book) with a chapter by G. C. Willenborg, D.D.S.M.M.F.F.I.C.D., Lasers and Electro-optics in Dentistry, a comprehensive article, pages 253-292.

- 1995 - "A Future For Laser Dentistry" from the Naval Medical Center, San Diego, California. (Fig. 1)

I START ON THE TEETH

I started in laser dentistry in 1961 at the Medical Center of the University of Cincinnati where, a first-of-its-kind, a comprehensive research laboratory was established through the John A. Hartford Foundation (Fig. 2). As director of the laboratory and a professor and chairman of dermatology in the College of Medicine at the University of Cincinnati and at the Children's Hospital of the Medical Center, Cincinnati, I was the founder and director of this laboratory with a staff of 18.[1,2]

It was possible to work in the biology and the biomedicine of laser technology and in its basic science areas. I did work on individual teeth on an optical bench and also on a molar of my own, which was to be removed later. This area of interest was selected for detailed research and development with the help of the dental research area of Procter and Gamble using the technique of Gray and Opdyke for making thin sections.[3] The ruby laser was used at a total fluence of 13,400 j/cm^2 and using a light transmission technique, which we had developed using a tappered quartz rod, it was possible to have the laser impact directly on the crown of my right upper second molar (Fig. 3) . Due to almost complete internal reflection of the laser within the quartz rod, almost no heat was produced in the rod during the laser light transmission. Thus, it was possible for me to hold this curved, tapered quartz rod directly onto the crown of the tooth with only a gloved hand. There was no pain produced either by holding the rod or in the impact on my tooth. During the procedure involving two laser impacts, I wore protective laser glasses, but photography of the actual impacts showed transillumination of my entire head (not safe). Fortunately, the light generated from inside my head was not focused on my retinae and no eye damage occurred. Thin sections showed in detail the extent of the laser reaction in the sections of this exposed tooth (Fig. 4) . Pictures show the extent of the deep damage to the tooth. Additionally, for treating several dental caries, the Ruby laser was again used at a total of 13,400 j/cm^2 (Fig. 5) .[3]

We continued laser dentistry through 1963 and reported in 1964 the results of using other treatments with the fiberoptics that we had. We demonstrated that it was possible to do extensive selected spot treatments for any place in the oral cavity using various laser systems with these quartz rods and fiberoptics.[4] I was also fortunate in having a brother, Bernard Goldman D.D.S., who was practicing general dentistry in Cincinnati at that time. He supplied the technical help in addition to the help from the research personnel from the Dental Department at Procter and Gamble. He also supplied the reality of the position of the expensive lasers in the clinical practice of dentistry in the 1960s. He showed me at that time there was very little interest in lasers in general practice dentistry with its low real value and high cost of experiments and no funding specifically for research in laser dentistry (Bernard Goldman: personal communication, 1993).

CURRENT REVIEW OF LASER DENTISTRY

Laser dentistry was just beginning to activate interest, especially in the Asian countries, although there was a lot of interest in the fusion of enamel and the effect on dentine. We had worked with Stern and Sogannes,[5] true pioneers from Southern California until the untimely death of Stern. Stern's dream with the lasers was to make teeth resistant to infection.[5] One of the techniques used was to fuse enamel so it would be impervious to the attack of caries. Unfortunately, with the laser systems of that time, it was not possible to easily reach between the teeth.

The posterior aspect of the teeth maintained some degree of safety with the reflection and spread of the laser impact. There was also concern about heat reactions in the pulp cavity. We did a number of temperature tests on the surface and on the inside of the pulp cavity with the impact of various laser systems on the tooth. What did seem of interest during this period was the possibility of dental surgery.

Dental surgery done in cooperation with dental surgeons, was done for leukoplakia, carcinomas, vascular lesions, and retention cysts. Much later, in 1994, a Q-switched Ruby laser was used to treat the pigmentation of amalgam tattoo on the gingiva.[6] Previously, only transplantation was possible for this disfiguring lesion. The vascular lesions, especially of the port wine type, were treated together with dental surgery; here the Ruby laser was used with local anesthesia and nerve block. For more extensive lesions, ambulatory laser dental care can be done under general anesthesia.

At this time, I tried unsuccessfully to interest the general dentistry practitioners to use inexpensive helium neon lasers to transilluminate teeth for cracks and roughness and to use fluorescence as a diagnostic procedure instead of dye chemicals.[7] Experiments for melting fillings, using hydroxyapatite, required high output expensive laser systems. Inexpensive lasers only made pictures on infected areas and joints without any real treatment value.

Studies of interest were those of B. J. Elkhagen and Sundstrom[8] of the fluorescence of the tooth by the argon laser in addition to other laser systems which transmitted through the tooth and enabled us to see cracks or splits. This fluorescence of the tooth is important for diagnostic features many years hence - this will be discussed.

The other concerns of treatment at this time, especially in Europe, was called laser biostimulation. In order to try to find laser instruments that were not expensive, not strong, and had beautiful lights, low output laser systems were used in many uncontrolled experiments. False conclusions were drawn about the value of this technique at the cellular and tissue level and about the continued confusion about evaluating results in rough, clinical experiments. By this time, there was laser expertise in other countries, especially with Jacques and Francoise Melcers of France.[9] Their detailed and controlled experiments helped to encourage the spread of laser dental therapy.

NONSURGICAL MEDICINE

For this book, I was able to obtain the great help of G. C. Willenborg, who is an experienced dental expert in electro-optics, lasers and holograms. He wrote a long chapter on Lasers and Electro-optics in Dentistry.[10] This was one of the best reviews of laser dentistry at the time and it included real proposals for the future.

We also had an opportunity at this time, in the history of laser biomedical technology, to see what the market advertising effect had on laser biomedicine with special reference to laser laparoscopic cholecystectomy, laparoscopy and dental laser instrumentation. Here, the advertisers controlled the use of laser systems rather than by clinically-controlled research. Expensive and sometimes unnecessary instruments were forced on the general surgeon and especially on the dentists. For general surgery, laparoscopy had been low key in the surgical development for laser technology. However, the dentists were impressed and bought expensive laser instruments for soft tissues which could not be used. This crisis led to the true realization of how to work for progress in laser treatment programs, and this led to the significant developments for the future, as is evident by the laser dental programs at the present time.

A FUTURE FOR LASER DENTISTRY

The obvious use for the future is the developments by the Academy of Laser Dentistry on curriculum guidelines and standards for dental laser education in all phases (Fig. 6) . This extremely important document showed how the many areas of laser dentistry - from learning, routine practice, surgery and research - can be done in an effective manner to provide the dentist with adequate and proven instrumentation. Lasers are still expensive and as the early days indicated, it was still too expensive for routine practice. Laser instrumentation would be limited to dental surgeons who could afford them, as was shown in 1986. But there are laser instruments which are not expensive for diagnostic purposes and for laser surgery. However, for the future, many new developments in laser medicine and surgery can now be studied in large dental centers that are available for research.

Probably the most important technology for the dentist is Photodynamic Therapy (PDT) for early diagnosis and treatment of cancer.[11] This is available in research programs and will soon be definitely on the market as one of the great advances in cancer diagnosis and treatment. In this technology, special chromophores that relate to near specific absorption by cancer tissues will be available parentally, and in relationship to some daily uses topically, especially in the buccal cavity. These tissues are then activated by laser light and sometimes even by intense non-laser light or red lights to energize the oxygen to produce necrosis of the tissues in which the cancer chromophores are localized. This has been very effective in many fields of medicine today, especially detection and early treatment of cancer of the lung, bladder, and stomach, and it can be adapted to early detection of cancers and treatment in the buccal cavity. The advantage of large surfaces covered with thin mucous membrane is that it allows for deeper light penetration for better diagnostic and treatment purposes (Fig. 7) . The topical chromophore preparations now available for research in PDT could be used in dentistry so that malignancies could be recognized in their early form. This is quite proper for learning by the dental surgeons for it is often an accomplishment to be able to recognize early cancer before the next door neighbor does.

Next, a research consortium which I have attempted to establish with Dougherty, the great world expert in PDT as the director, includes such capable people as R. Rox Anderson of

Wellman Laboratory in Boston; Richard Straight from the University of Utah; Our Navy experts Drs. Kerr and Steger; and the research of laser expertise from Navy Research and Development (NRaD) of Richard Scheps. We are trying to find out how to recognize early cancer which is not on the surface and not in a cavity - a similar problem to that which the Navy has in detection of submarines in turbid media. There are fascinating developments in research optics at the present time that can assist in the search for subsurface cancer - a project in which the Navy has been interested for some years (Richard Scheps: Personal communication, 1994). These techniques include attachments of fiberoptics to CCD cameras for monitoring and imagery deep within the tissue. Special techniques involve individual layers. For example, in superficial melanoma, we can use the confocal scanning microscope with living skin. There are also several techniques for recognizing targets under the surgace. One is optical phase conjugation, which uses special optics in which the reflected beam comes back along the same path as the incident beam. In range-gating techniques, the laser beam is passed briefly through a very fast electric shutter so that the scattered beams are minimized in producing a direct beam imagery. Specific imagery is determined by the specific time for closure of the shutter to produce the desired imagery as previously determined. There is great interest in tissue autofluorescence and induced fluorescence for more accurate diagnostics that these investigators claim for the diagnostic technique without the need for surgery. (Figs. 8-15)

So -- here in dentistry you have an extensive cavity which allows detailed examination of the surface and easy access to subsurface tissues for diagnostics and treatment procedures of many types. Therefore, laser dentistry has a great potential for laser diagnostics and treatment in the future. (Fig. 16)

Assistance in such technologies comes from Richard Scheps, our laser consultant from NRaD, who will also give advice on image detection by optical instruments with monitors, optical phase conjugation, and range-gating (Fig. 17) . With the expanse of the thin-layered buccal cavity, it is possible to extend this much needed research into the field of diagnostic and treatment of buccal cancer in laser dentistry. The future is great for such research and development. (Figs. 18–21)

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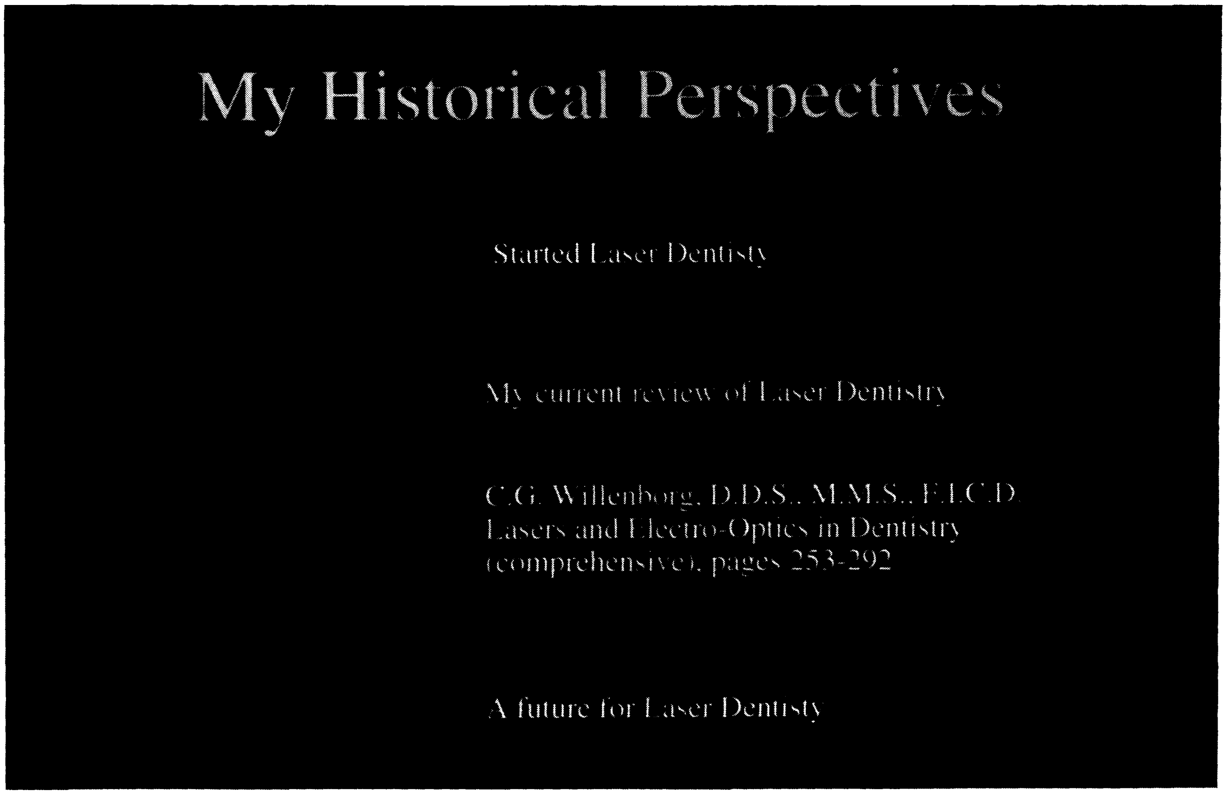


Fig. 1. My historical perspective

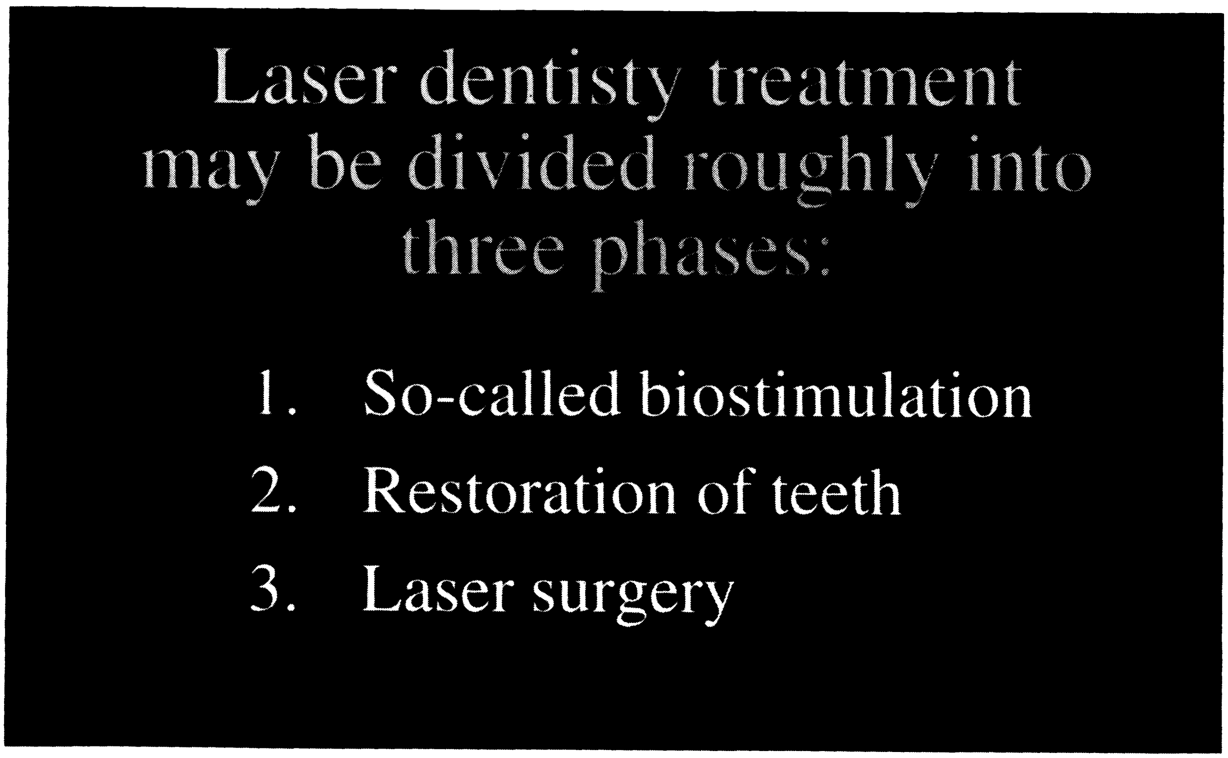


Fig. 2. Laser dentistry treatment

Fig. 3. Ruby laser treatment of upper second molar through a curved tapered quartz rod held by patient to rest on crown of tooth; with total internal transmission of laser, no hazard by holding rod. Treatment was on spots of caries. (Journal of the American Dental Association 60:601-5, March 1965).

Fig. 4 Photo of the direct impact of laser in patient of Fig. 3 with extensive transillumination of the orbit.

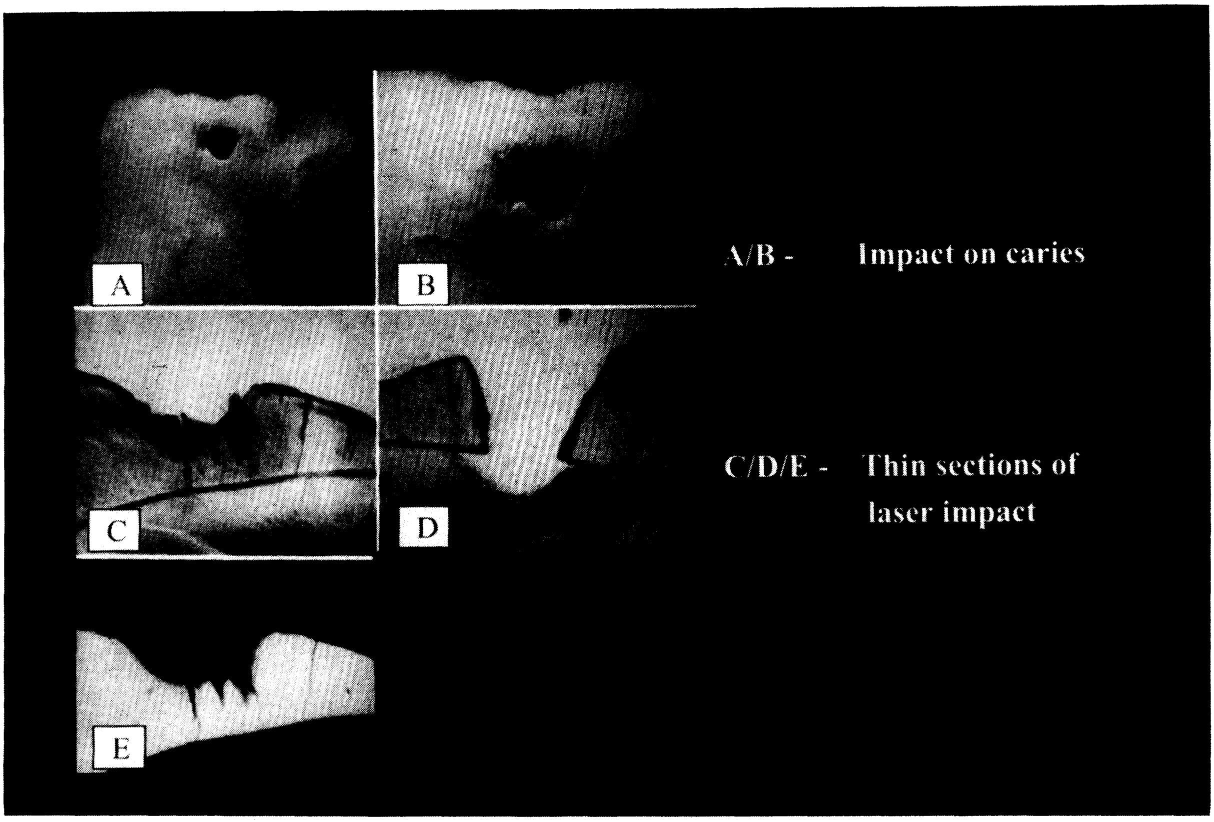


Fig. 5 (A) Necrosis of pigmented carious area with total fluence 13,000 j/cm^2; (B) large irregular crater of laser impacts; (B) thin section showing broad destruction of enamel; (C) thin section of caries showing separation of enamel and dentin; (D) thin section showing decreased area of caries that may indicate caries unaffected area of laser impact. (Journal of American Dental Association 60:603, March, 1965).

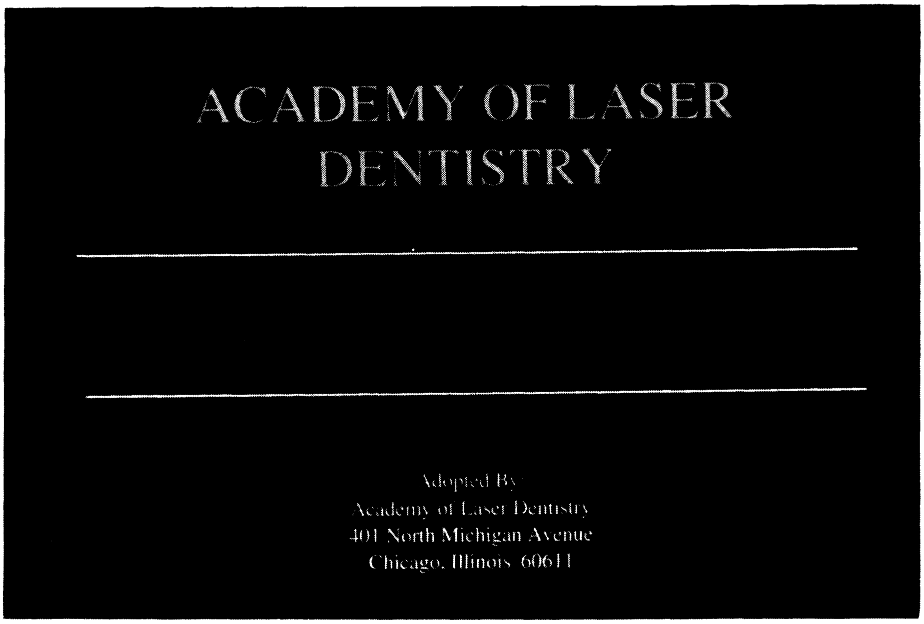


Fig. 6 Detailed program of the American Academy of Laser Dentistry.

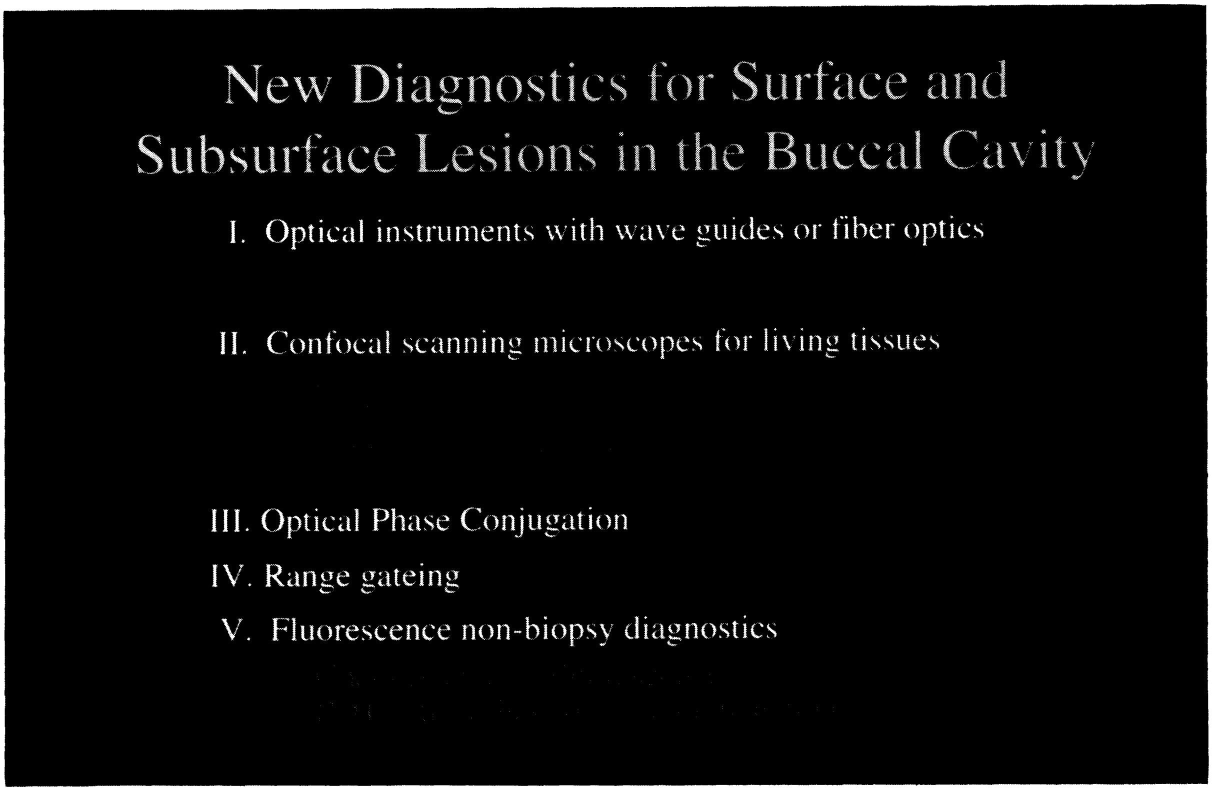


Fig. 7 New diagnostics for surface and subsurface lesions of the mouth.

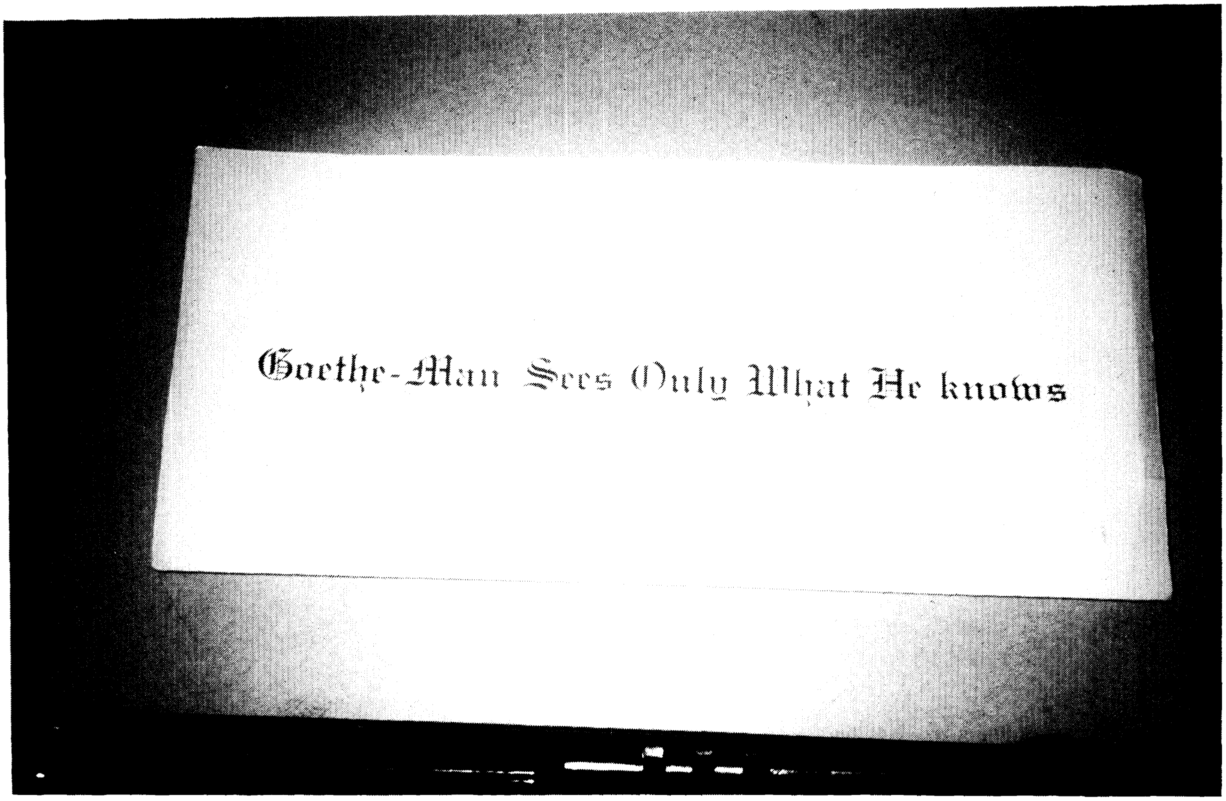


Fig. 8 Goethe: man sees only what he knows.

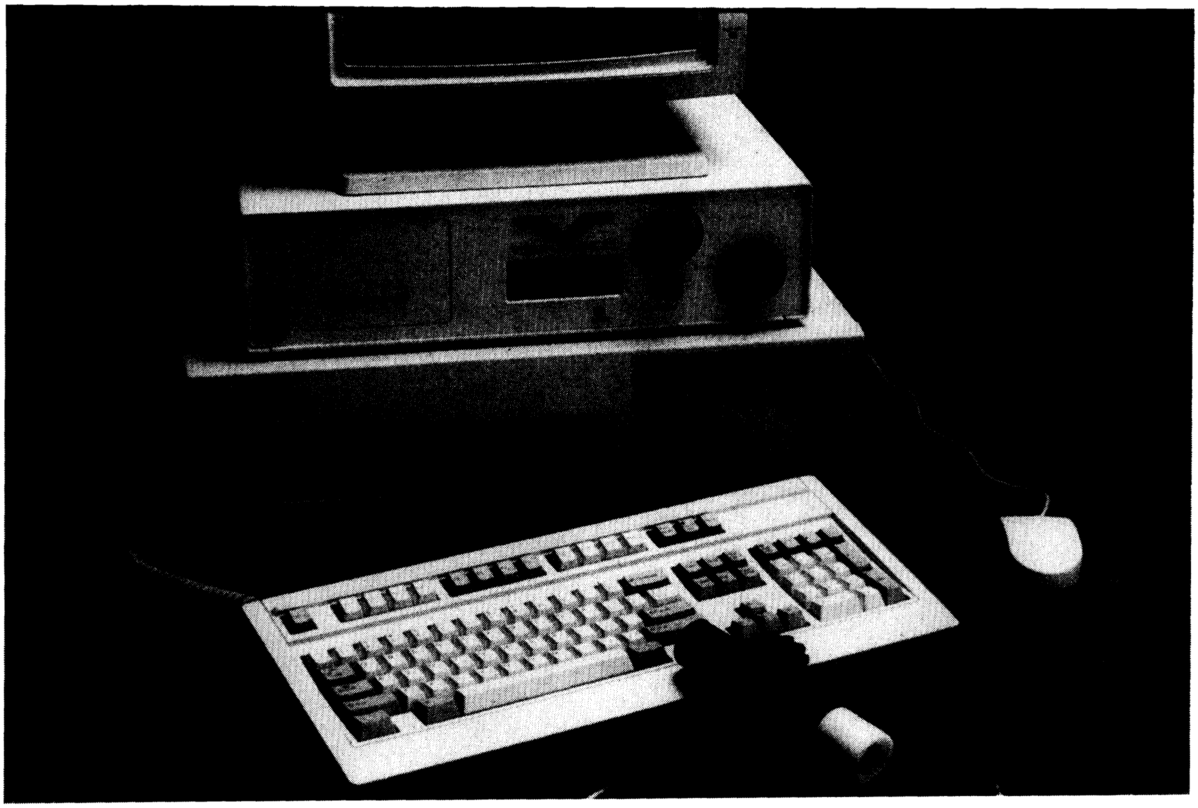


Fig. 9 Direct photograph of clinical case in computer record.

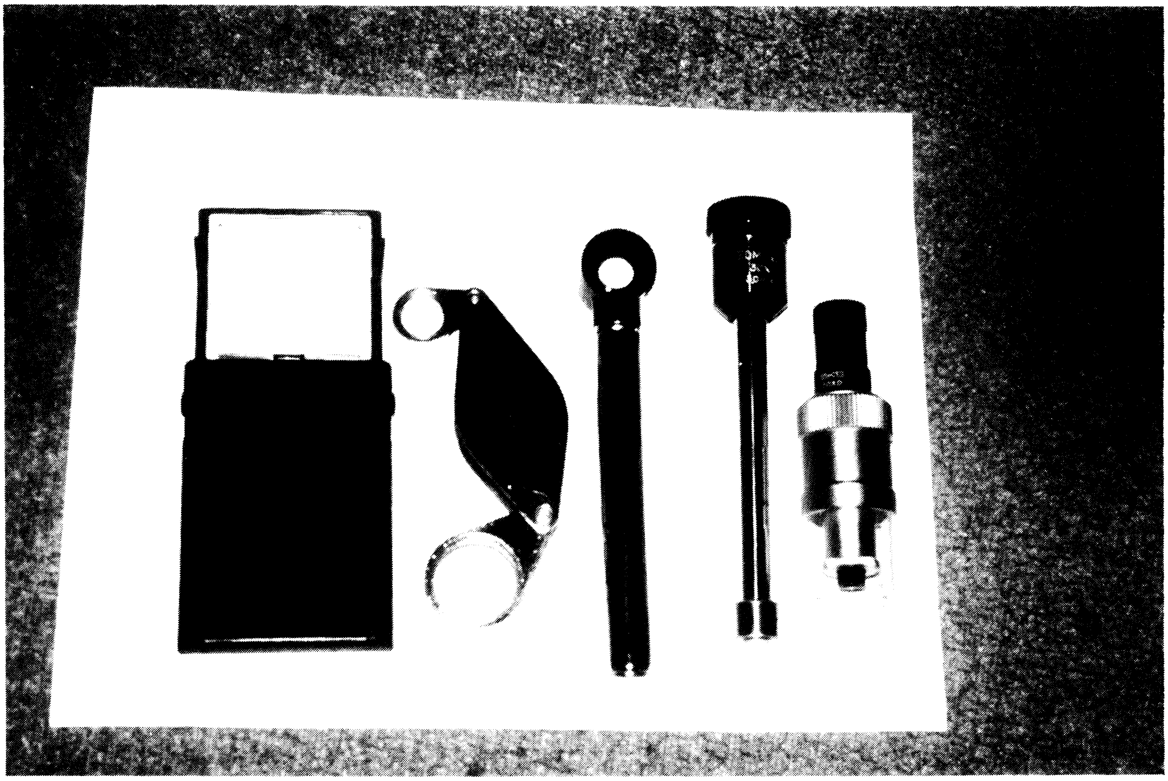


Fig. 10 Array of magnifiers and portable microscopes to observe earlier detail of mouth lesions.

Fig. 11 The Dermatoscope for detailed analysis of pigmented spots application of oil...greater detail of pigmented spot.

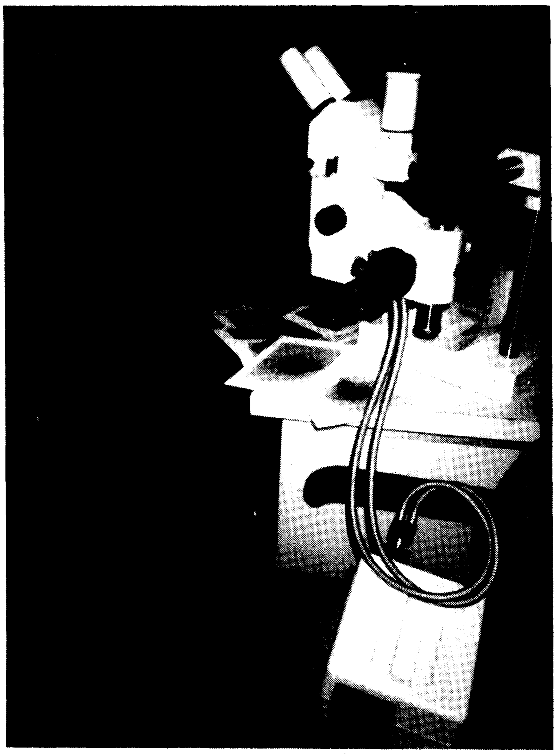


Figure 12(A)

Fig. 12 (A) Coaxial polarizing microscope of Anderson for special details of pigment spots and blood vessels for accessible areas and fiber optics for inaccessible areas. (B) dorsum of hand (C) accentuation of pigmented area.

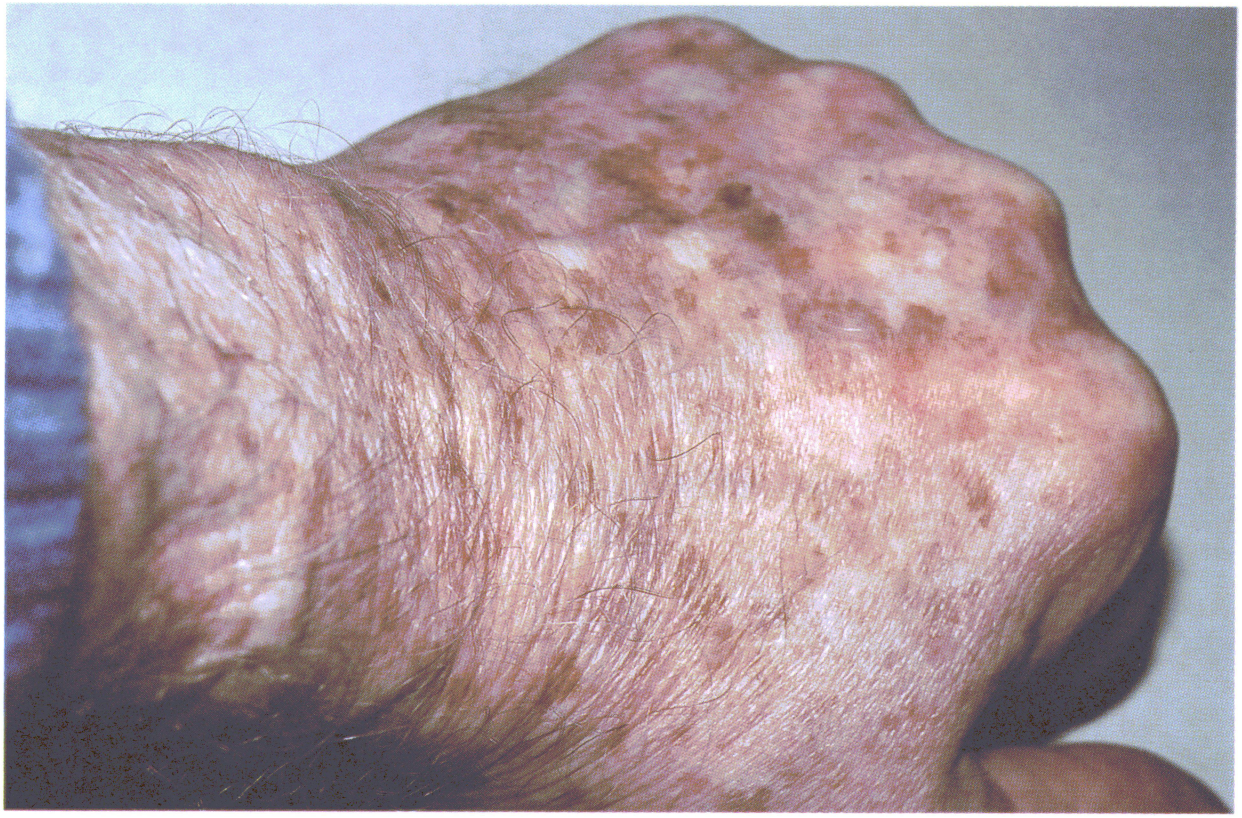


Figure 12(B)

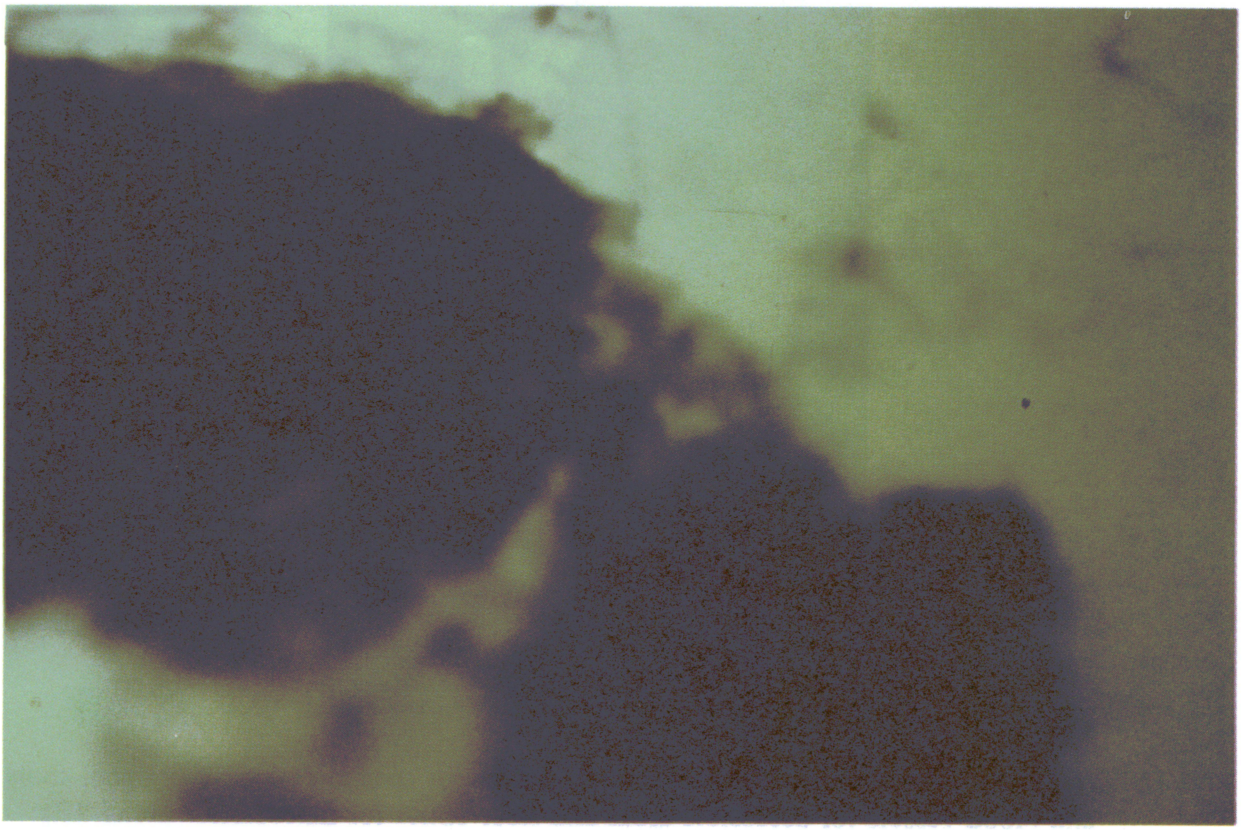


Figure 12(C)

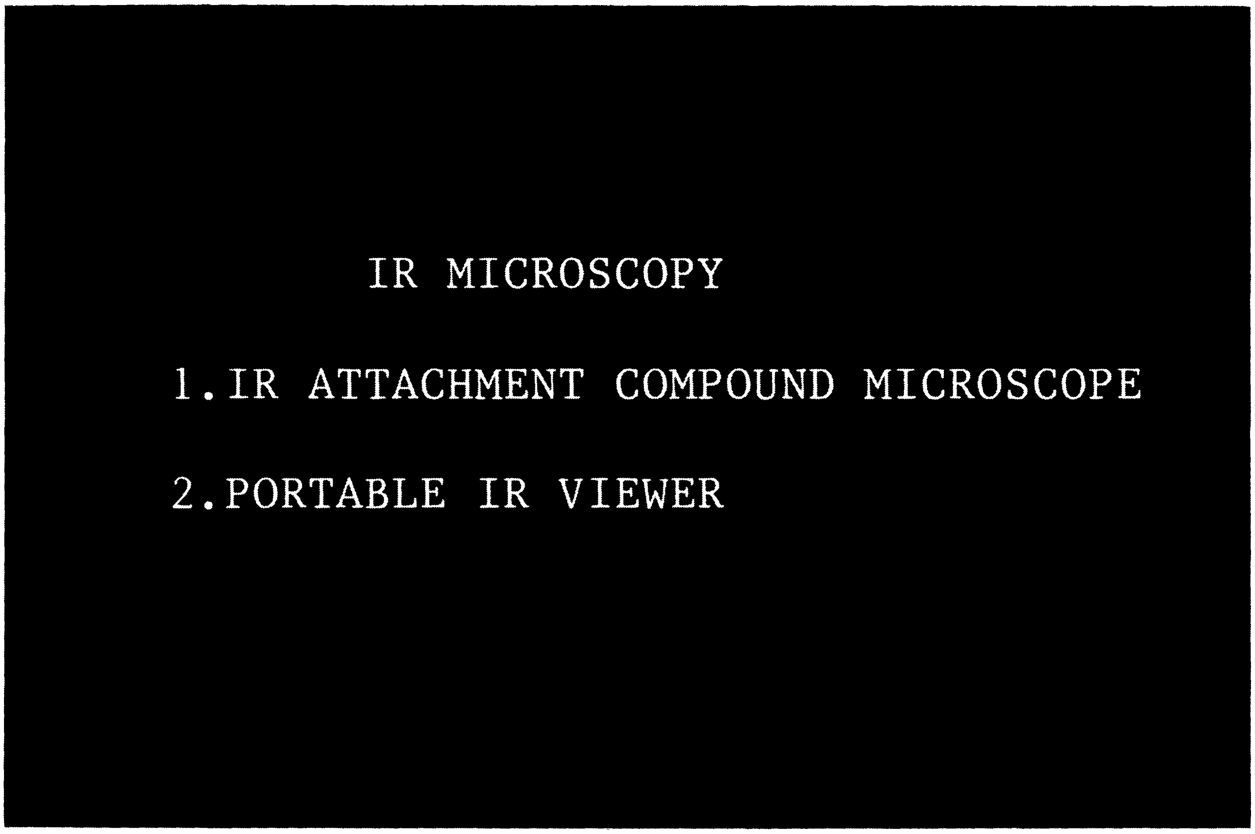
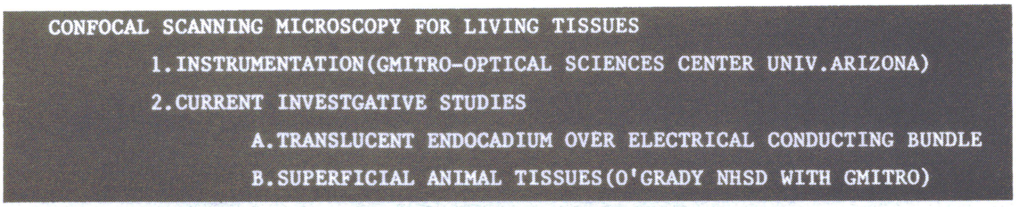
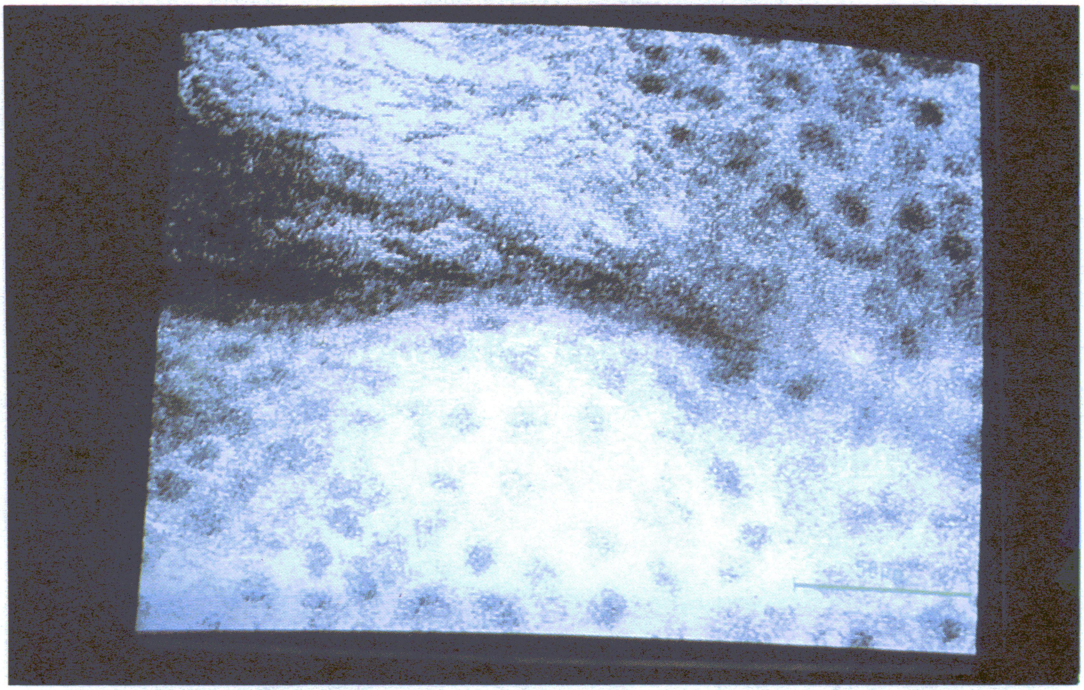


Fig. 13 Infrared microscope especially for blood vessel studies.





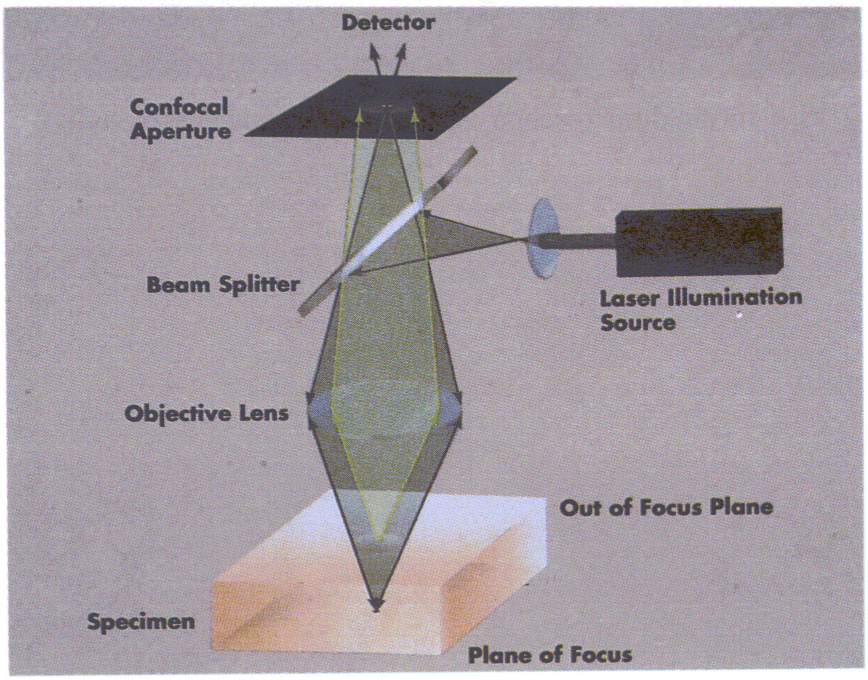


Fig. 14 Confocal scanning microscope for living skin in situ and fresh tissues and superficial tissues. Cornea-Masterson. Epidermis—for early superficial melanoma 80× Masterson, Aziz; Goldman: O'Grady. From deep tissues to surface by endoscope—Gmitro; Aziz.

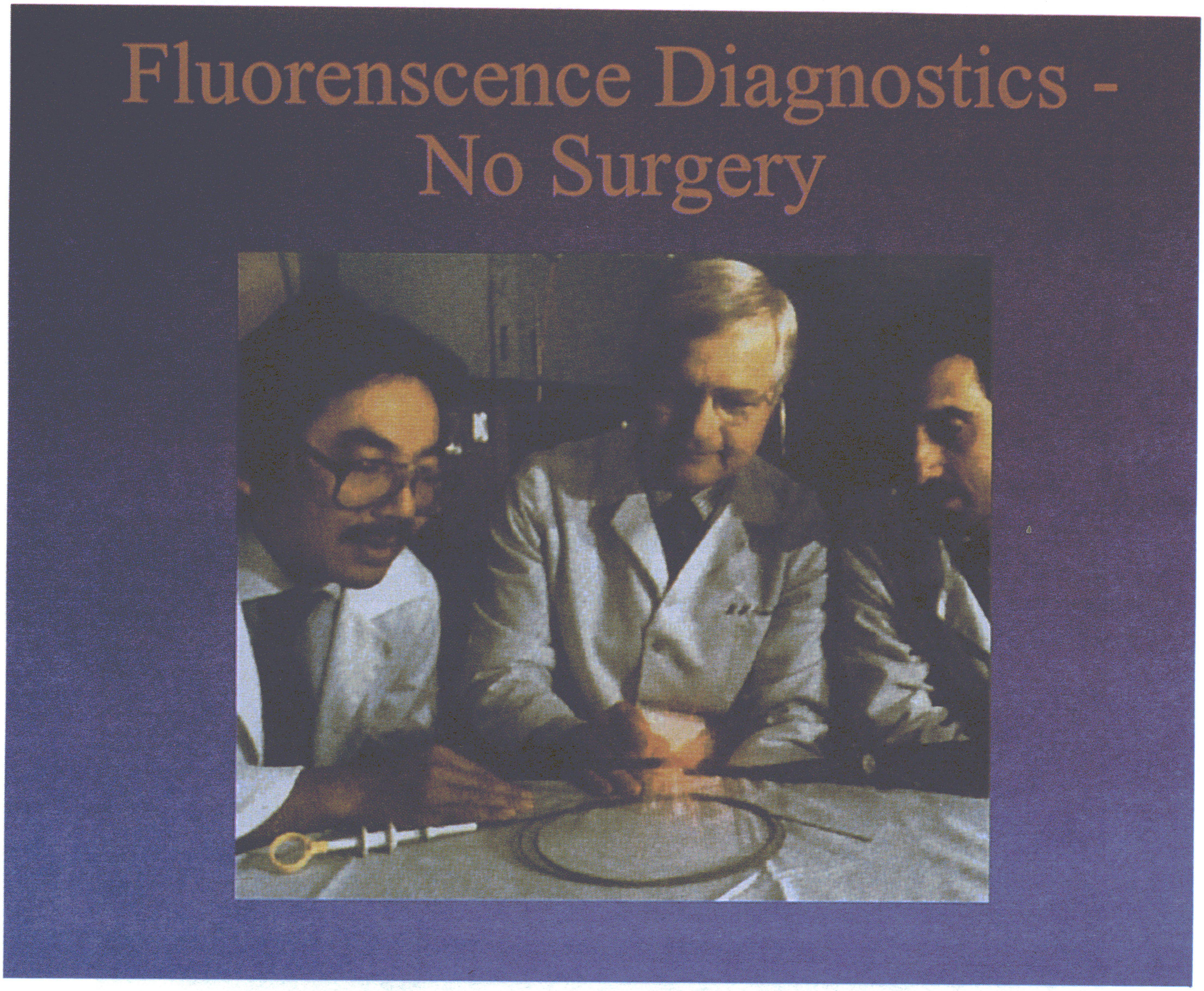


Fig. 15 Fluorescence cancer diagnosis as a nonsurgical biopsy (VonDinh;Overholt;Pasijihour).

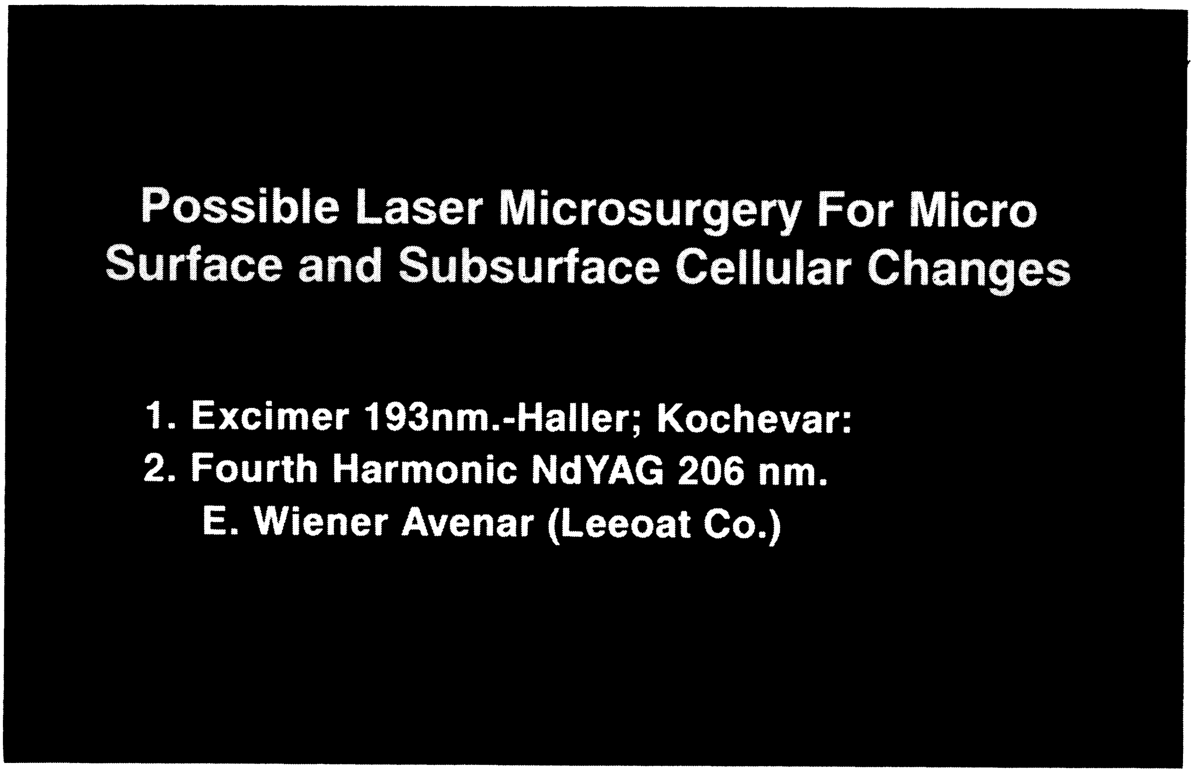


Fig. 16 Laser microscopy for early minimal changes.

Fig. 17 Proposed subsurface imagery from the Naval Research Administration through Richard Scheps, PhD.

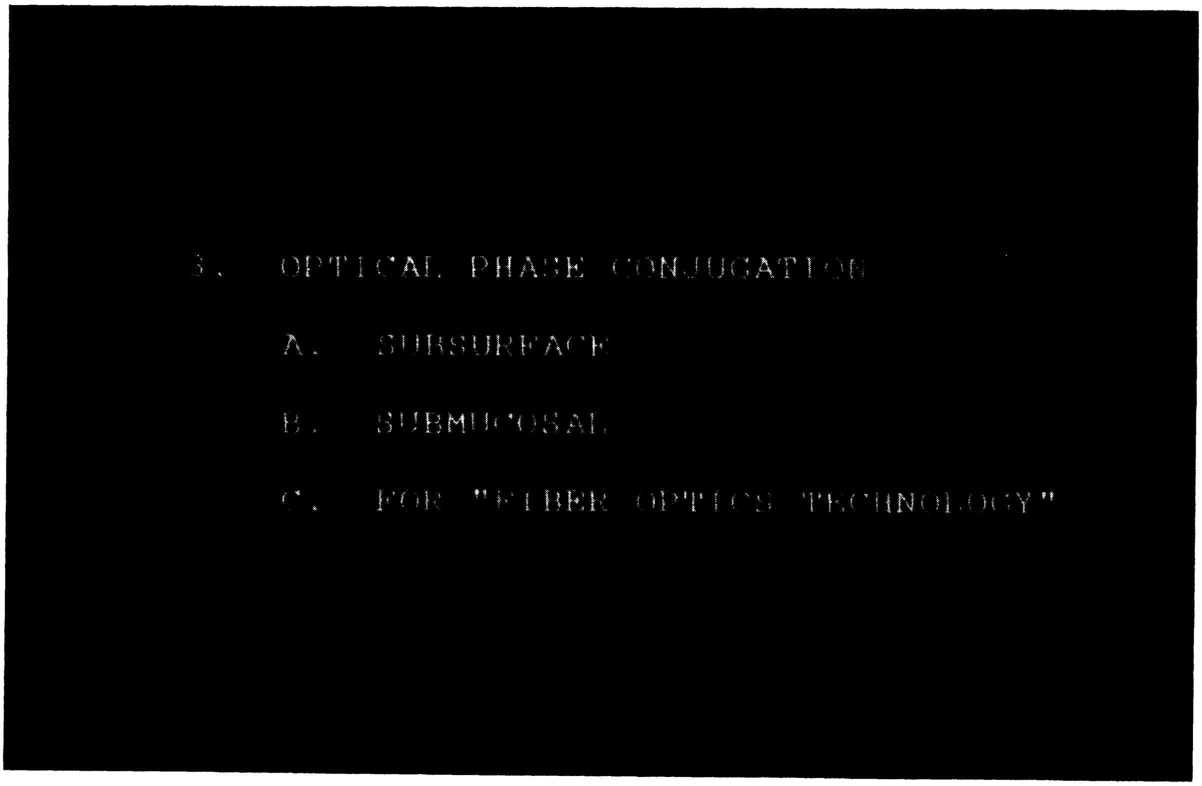


Fig. 18 Optical phase conjugation for cooperative cancer research for early diagnostics with the Department of Dermatology of the Naval Medical Center in San Diego.

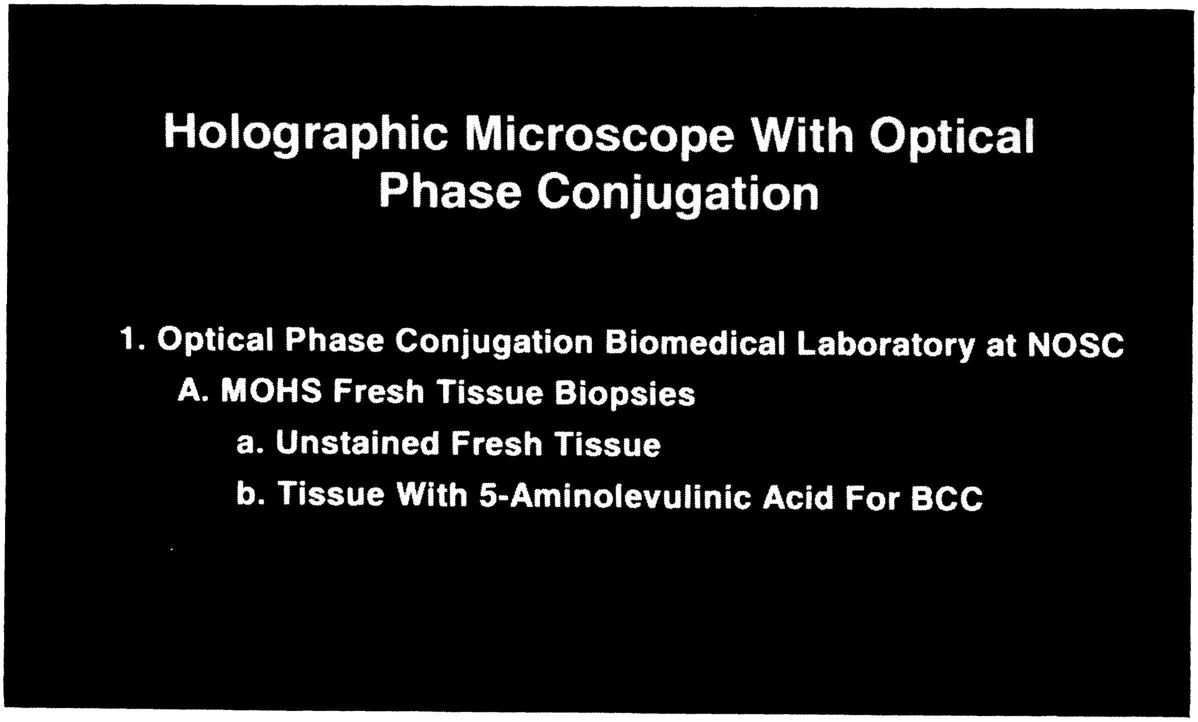


Fig. 19 Special microscopy for early diagnosis of skin cancer with 5 AL:A.

LASER DIAGNOSTICS

1. BASIC PHOTOBIOLOGY

2. IMAGERY

  A. TRANSILLUMINATION ALL PHASES
  B. CHROMOPHORES-RESEARCH AND DEVELOPMENT
  C. FIBEROPTICS
  D. MICROSCOPY
  E. "SILICON RETINA"-MEW RECOGNITION SYSTEM

3. SPECTROSCOPY

  A. TOXICOLOGY
    a. ARSENIC-MEDICOLEGAL
    b. LEAD - ASSAYS IN CHILDREN - HAIR
  B. CARDIOLOGY-ATEROMAS
  C. ONCOLOGY- CARCINOMA PF TH BREAST (OLFANO)

4. CIRCULATION

  A. DOPPLER
  B. PULSED THERMAL RADIOMETRY (NELSON-PORT WINE MARKS)
  C. SKIN TEST EVALUATION

5. SENSORS

  A. PRESSURE
  B. THERMAL
  C. CHEMICAL REACTIONS
  D. SURVEILLANCE
  E. ELECTRICAL ACTIVITY
    a. CARDIOLOGY
  F. BIOSENSORS LIGHT (LIGHTING BUGS;MARINE BACTERIA)

6. ENZYMOLOGY

  A. NADH (CARDIOLOGY)

Fig. 20 A comprehensive review of laser diagnostics for many organs.

For Prevention

Precancer, Basal Cancer, Squamous Cancer
Melanoma in High Risk People

1. Measurment of Sun Exposures
2. Studies of the Interactions of Genetic Factors
3. Biomedical Microscopy of Living Skin Surface and Subsurface
4. Detailed Imagery
   - A. Melanocyte Changes
   - B. "Early" Dyskeratotic Cells
   - C. "Early" Cancer Cells
   - D. Vascularity Patterns

Fig. 21 Some values of a prevention research program for dermatology and also dentistry by J.H. Kerr, Capt. USN, and J.W. Steger, Capt. MC USN, and Leon Goldman, M.D. of the Naval Medical Center, San Diego.