This brief history of optical thin films at The Institute of Optics reports some of the activities from the late 1930s to present. The history of optical thin films at the Institute can be organized into three periods, each with a laboratory designed for specific purposes. The earliest lab organized by Mary Banning supported the World War II effort. Philip Baumeister sparked an energetic research and teaching program. The third lab supported construction of the Omega Laser at the Laboratory for Laser Energetics.

The material for this brief history was gathered from library archives, from personal communications, and from my recollections as a student and as professional staff at the Institute.

The Early Years: Late 1930s–Early 1950s

The earliest mention of optical coatings at the Institute is by Hilda Kingslake. “In the late 1930s (Brian) O’Brien set up an evaporating unit for metallizing mirrors, and when later the thin-film antireflection coatings were introduced, he adapted his machine for this purpose.”

Institute of Optics faculty, students and staff focused on helping the war effort. “Dr. O’Brien (Institute of Optics Director) initiated an active program in response to the National Defense Research Council effort on behalf of the war [WWII]. Mary Banning established the Thin Film Laboratory equipped with vacuum coating chambers to carry out a research program.”

A recent communication from Brian O’Brien Jr. describes some of the activities at The Institute of Optics during World War II. “I did work for Mary Banning, as did several other undergraduates. I don’t remember just when she set up the evaporator lab but we did a lot of coating work during the war. This included multi-layer low-reflecting coatings, nickel neutral density filters, partial reflecting coatings, etc. I remember one job we did producing 50% coatings on 45/90 prisms for our entire fleet of submarine periscope cameras. These were actually not done by vacuum evaporation but by heat decomposition of titanium tetrachloride into titanium dioxide coating on glass.”

“In 1947 Mary Banning wrote a classic paper explaining how to deposit multilayer filters and how to control their thickness.” She also described the 1943 development of the polarizing beamsplitter in this paper as well. During the late 1940s Alan Gee developed a film thickness monitoring system of sufficient accuracy to enable Harry Polster to produce a frustrated total reflection filter.
Dr. Polster also developed the fifteen-layer all-dielectric narrow band interference filter while at The Institute of Optics.

The Baumeister Era: 1959–1979

Philip Baumeister was the premier academic researcher, teacher, and student advisor working in the discipline of optical coatings. Philip drove the use of digital computers to design and analyze multilayer thin films, and led research across a broad range of optical coating application areas including synthesis and design, metrology and instrumentation and fabrication, especially UV filters and materials. Philip facilitated dissemination of optical thin film technology by organizing professional meetings attended by international audiences.
George Dobrowolski of the National Research Council (Ottawa) recently told me a story that illustrates Phillip's low-key, substantial influence. George established an international reputation developing mathematical techniques for thin film synthesis. George frequently traveled from Canada to the University Computing Center in the early 1960s to use Philip's thin film analysis code. George recalls the computer as an IBM 650 that required input and

*John Urbach and Phillip Baumeister.*

*Barry Dame and Big Berthe.*
output via punched cards. A card reader interpreted the output deck, and the information was sent to a printer. Philip’s unselfish cooperation enabled George to achieve his early theoretical successes. Dobrowolski concluded, “I owe Philip a large debt of gratitude.”

Philip established his lab with his coating machine, “Berthe,” as the star. Berthe arrived in 1962. Berthe was equipped with electron beam and resistive evaporation systems enabling deposition of a wide range of thin film materials. Berthe and associated metrology instrumentation enabled the pioneering fabrication of induced transmission ultra-violet interference filters.

During a period when optical coating designs and fabrication techniques were often closely held, Philip made substantial contributions to the dissemination of technology by means of international symposia he organized. Two symposia are worth noting. In June 1966 he coordinated a three-day series, “Design and Fabrication of Multilayer Optical Filters.” Principal speakers included recent Baumeister Ph.D. students V. R. Costich and E. Delano, J. A. Dobrowolski (National Research Council, Canada), O. S. Heavens (University of York, England), R. J. Pegis (St. John Fisher) and D. L. Perry (Bell Telephone Laboratories, New Jersey).

Philip followed up with another three-day series in June 1967 titled “Optical Thin Films and Multilayers.” Philip was assisted by visiting professor J. Roland Jacobsson of the Institute for Optical Research (Stockholm, Sweden). Roland was the leading authority on inhomogeneous optical thin films. He spent one year teaching at The Institute of Optics. Other lecturers included William R. Hunter (U. S. Naval Research Laboratories, Washington, D. C.) a leading authority on the properties of ultra-violet materials; Michael Smith (Xerox Research Laboratories, Webster); and A. Francis Turner (Bausch & Lomb, Rochester). Turner was a pioneer in optical thin film development and applications from the 1930s onward.


The Laboratory for Laser Energetics started in the late 1960s with collaboration between faculty members Michael Herscher, Institute of Optics, and Moshe Lubin, Mechanical and Aerospace Sciences. By the mid 1970s LLE was funded by a consortium of private firms, the University, and state and federal agencies to establish the National Laser Users Facility (NLUF). The objective was to investigate the interaction of intense light with matter, to study basic physics and laser fusion. The path forward included building the twenty-four-beam-line Omega laser system, constructing a facility on the East River Road campus, and assembling the professional staff to build and operate Omega and conduct the research. The funding was associated with an aggressive schedule for development and construction of Omega. The technical basis for Omega was demonstrated with the successful four-beam-line Delta system located in the Gavett Hall lab. Omega’s scaled-up requirements for radiant energy densities, laser power, pulse repetition rates and the coherent nature of light posed new challenges. Substantial scaling of design concepts and some invention associated with optical materials and processes were required to build Omega.

In 1975, after discussions with Moshe Lubin (director of LLE) and Brian Thompson (dean of engineering), I accepted an offer to establish and operate an optical coating lab at
The Institute of Optics to support the thin film development and production requirements for LLE. The motivation for establishing the coating lab on campus was straightforward. Coating requirements for the Omega system limited the number of reliable commercial suppliers, and schedule was a critical factor in the LLE plan. Some of the critical optical coating specifications included state-of-the-art film thickness uniformity over large substrates and in large quantities. The resultant thin films had to withstand intense laser irradiation with production rates sufficient to satisfy a demanding schedule. In addition, some of the substrates such as the laser rods were very expensive and had lead times measured in months. One or two commercial firms demonstrated the ability to meet most technical requirements. They were both located in California and they committed their capacity to supporting a similar program at Lawrence Livermore National Laboratory (LLNL). The risks for LLE were associated with schedule reliability and the probability of damage to precision optical components due to shipping across the country. Moshe Lubin decided a dedicated, reliable optical coating lab was essential to the successful development and operation of Omega.

I started planning the coating lab in the summer of 1975. I developed a schedule consistent with LLE milestones, submitted a budget and developed requirements for the lab. About this time, Jay Eastman joined LLE as Omega program manager. As program manager, he also was manager of the coating lab. That was fortunate for me because Jay became a valued colleague. During the planning stage, we had to make decisions that broke new ground and relied solely on our professional judgment. I am grateful for Jay Eastman’s counsel, which enabled our lab’s success.

We were assigned space in the recently vacated Gavett Hall engineering machine shop (the shop moved to a better facility in a stand-alone building). When I first entered the empty shop and noticed the aroma of cutting oil, I wondered how we would clean it up so our coatings would not suffer organic contamination. The University had a very competent contractor, and proper application of epoxy paint accomplished the objective of sealing the contaminants. While the facility was prepared, we ordered two coating machines, one forty-eight-inch and one seventy-two-inch box coater. We also ordered metrology equipment and components for the substrate cleaning facility. We worked long hours for

*Jay Eastman on the bank of the Genesee.*
six months integrating and shaking down the equipment to make up schedule slips due to late delivery of equipment. An additional three months was needed to establish and stabilize processes for inspection, pre-coat cleaning, and thin film performance verification.

The LLE plan called for building the first six of twenty-four beam lines as an engineering model. The six beams, called Zeta, were to be operational in 1978. The coating lab was up and running by the end of 1976. We spent 1977 developing and producing coatings for the Zeta optics on schedule. Steve Jacobs, chief optical scientist for LLE, provided substantial support materials and special metrology support for the lab. Steve also led the development of improved laser glass at Hoya. Ken Walsh directed the optical metrology team that supported the coating effort.

The most challenging coatings were large thin film polarizers. Polarizers made of crystals or other materials would not withstand the laser power and could not be made in the aperture sizes needed. The thin film polarizers were up to seven inches by fourteen inches and required thickness variations less than 1 percent. Other coatings included anti-reflection coatings on the ends of 90mm laser rods, large forty-five-degree reflectors with differential phase change upon reflection for “p” and “s” components of less than one and two degrees, and coatings effective at 1.053 microns and 0.351 microns for frequency-tripling applications.

Zeta was very successful, and we started work on the balance of the twenty-four beams. The schedule called for Omega to be operational during 1981. The coatings had to be completed in about eighteen months. We ramped up to two full-time coating technicians and relied on our metrology and materials support teams to help us complete the coatings on schedule. In all we coated about three thousand optical elements.  

Optical Coating and LLE: 1980–Present

When the coating assignment for Omega was complete, I decided to make a career change and joined Eastman Kodak Co. in 1980. Doug Smith joined LLE shortly thereafter. He managed the move of the coating lab to LLE and expanded the facility for greater coating capacity. Doug operated the lab to successfully coat optics to convert Omega to a UV system.

Today the coating lab continues to thrive and contribute, providing coating services to LLE and LLNL. The Institute of Optics/LLE coating lab provides more than half the critical polarizer and large turning mirror coated optics for LLNL. The tradition of thin film optics contributions to major programs started during World War II and continues today in support of laser fusion research.