
THE NATIONAL PRECISION OPTICS SKILL STANDARDS FOR TECHNICIANS 2ND EDITION

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OP-TEC
National Center for Optics and Photonics Education



Endorsed by:



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INTRODUCTION

About Precision Optics Technicians

Precision optics technicians (POT) produce, test, and handle optical (infrared, visible, and ultraviolet) components that are used in lasers and sophisticated electro-optical systems for defense, homeland security, aerospace, biomedical equipment, digital displays, alternate energy production, and nanotechnology. POTs also integrate precision optical components into electro-optical systems and maintain them.

Throughout the 20th century, precision opticians were mostly prepared under a “European-style, apprenticeship” training process, requiring the trainee (apprentice) to serve and learn for 6–8 years under the guidance and mentoring of a master optician. In the early 1970s a few community and technical colleges initiated training programs for optical technicians. Notably, the program at Monroe Community College was continually active for over 30 years.

Today, there is a perceived shortage of POTs that could require our country to outsource this work to foreign nations—a situation that would compromise our nation’s security and sacrifice a vital sector of future economic development.

Several factors have contributed to this shortage:

- The apprenticeship training for POTs is not subscribed to or adopted in our country to any significant extent.
- Many experienced POTs have retired, and more are expected to retire in the near future.
- Most community colleges that have offered education and training in precision optics have discontinued their programs due to faculty retirements and poor support.

Furthermore, the skills and knowledge necessary for success in today’s precision optics jobs require more education in science and technology (particularly in materials science, optical phenomena, and the operation of optical instruments and interpretation of their measurements). Also, the manufacture of most precision optics (particularly spherics and aspherics) uses high-precision, computer numerical controlled (CNC) machines. POTs are often required to set up, operate, calibrate, and maintain this equipment. Clearly, the job requirements for POTs have been raised, and significant changes are required in the education and training of these technicians.

OP-TEC: The National Center for Optics and Photonics Education

In 2006, the National Science Foundation (NSF), through its Advanced Technological Education (ATE) Program, established OP-TEC: The National Center of Excellence in Optics and Photonics Education. In 2010, the NSF awarded OP-TEC a three-year extension in its funding through a grant with the University of Central Florida. OP-TEC and its six Partner Colleges are committed to building the capacity of our nation's community colleges to provide the quality and quantity of technicians needed in the critical and emerging fields of photonics and precision optics manufacturing. OP-TEC projects the job market, maintains skill standards, designs curricula, tests innovative recruiting and teaching strategies, and supports ongoing and new AAS programs and retraining efforts at community and technical colleges by providing studies, technical assistance, and faculty development opportunities. OP-TEC also continually examines the field of optics and photonics to identify and support new education and training for emerging and changing technologies related to photonics.

The Need for Skill Standards

Skill standards are employer-driven statements of expectation as to what workers should know and be able to do on the job. Skill standards are employers' "specifications." They are the primary means by which employers communicate to educators their (the employers') requirements regarding the content of the courses and programs that will produce their future employees. Skill standards such as those contained in this document are necessary to ensure that technicians are well prepared for the challenges that await them in today's high-tech, globally engaged workplace.

About the *National Precision Optics Skill Standards for Technicians*

OP-TEC first developed and published the National Precision Optics Skill Standards for Technicians in January 2009. These standards, by design, are very broad and comprehensive. We do not expect every technician working in the precision optics area to have this full range of skills. Instead, these standards are designed to provide a base that employers and educators could customize to meet local industry needs.

The 2nd Edition of the National Precision Optics Skill Standards for Technicians follows the same basic design as the 1st edition. The 2nd edition of these standards represents the consensus of a broad cross-section of U.S. employers regarding the technical and workplace skills required of photonics technicians. They are designed to give educators and employer advisory committees a solid foundation for generating courses and programs that will enable U.S. two-year colleges (and their feeder high schools) to produce globally competitive workers. OP-TEC will use these standards to design model curricula and develop appropriate instructional materials.

For the purposes of developing the 2nd edition of these skill standards, we kept the same definition of POTs used in the 1st edition:

Specialists in the technical field of optical component fabrication where required surface tolerances are of the order of 1/16th wavelength (38 nanometers) and positional tolerances are 10 wavelengths (6350 nanometers). They work in optical shops for optics manufacturers, and in quality control (incoming inspection) departments for organizations that incorporate precision optics into various systems.

The Development Process

The 2nd edition standards were developed by OP-TEC using a three-phase process similar to that used by OP-TEC to develop the *National Photonics Skill Standards for Technicians*, now in its third edition.

1. *Draft development*—OP-TEC staff and a subject matter expert reviewed the 1st edition standards and made revisions that better organized the standards and clarified the critical work function, task, and skill statements. These revisions were incorporated into a document that became a draft version of the 2nd edition.
2. *Web review*—The draft version of the 2nd edition was posted online and a survey was developed that allowed photonics professionals to review the draft and make suggestions for revision. Thirty-three industry professionals completed this survey.
3. *2nd Edition Development*—The 2nd edition was developed using a panel consisting of an industrial representative, academic faculty member, and OP-TEC staff. This panel reviewed all input from the online survey and incorporated this input to update, clarify, and expand the 1st edition standards and generate the standards presented in this document.

2nd Edition Changes

The 1st edition of the standards was endorsed by the Florida Photonics Cluster, New York Photonics Industry Association, and American Precision Optics Manufacturers Association. These standards were developed with extensive input from precision optics professionals with both industry and academic backgrounds. As such, the first edition laid a solid foundation for defining the skills and knowledge required of a precision optics technician.

The results of the online survey conducted to develop the 2nd edition confirmed the completeness and accuracy of the 1st edition standards. Though suggestions were made for revision, all were minor and did not significantly alter the basic statements of skills presented in the 1st edition. However this review did lead to changes in the standards that should improve their usability, comprehensiveness, and clarity in defining the skills and knowledge required of precision optics technicians. The basic

differences between the 1st and 2nd editions are that the 2nd edition adds specificity and clarity to the critical work functions, tasks, and skills; organizes the technical skills into specific categories; addresses more thoroughly the technical skills required to effectively work in a cleanroom environment; and delineates specific procedures for handling and disposing of hazardous materials. The 2nd edition retains the collective wisdom of the photonics professionals that developed the 1st edition and provides refinements to these standards that have arisen from over three years of applying them in the field.

How the 2nd Edition Standards Will Be Used

OP-TEC views the development of the 2nd Edition of the Precision Optics Technician Skill Standards as a necessary first step to developing a new updated AAS-level precision optics curriculum and the instructional materials that will support it. The skill standards in this document will be the center piece of this development. OP-TEC considers this development one of its main objectives and intends to work closely with precision optics employers and two-year colleges from around the U.S. in implementing precision optics programs based on this curriculum. As more colleges adopt this program, the pool of qualified precision optics technicians will increase and provide the necessary base to ensure a viable, fast growing, and dominant U.S. precision optics manufacturing industry.

The OP-TEC staff invites you to review the standards and welcomes your recommendations for their improvement.

Daniel M. Hull, PE
Executive Director, OP-TEC

John C. Souders Jr., Ph.D.
Director of Curriculum

PRECISION OPTICS SKILL STANDARDS FOR TECHNICIANS

Critical Work Function 1. Identify, inspect, and qualify materials for manufacturing optical components.

Task a. Review incoming material certification sheets to match required specifications that include purchase order quantity and dimensional accuracy.

Task b. Inspect and evaluate material certification sheets to match print specifications

Task c. Ensure physical safety in handling hazardous materials by marking material containers with appropriate material safety data sheet (MSDS) identifications.

Task d. Follow material handling procedures to ensure physical safety, avoid contamination, and maintain material inventory and identification.

Task e. Maintain prescribed documentation of bulk materials using a job jacket or its equivalent.

Critical Work Function 2. Participate in the planning and verification of optical fabrication processes.

Task a. Use design specifications, technical drawings, and/or government documentation to meet specifications and tolerances.

Task b. Use basic processing techniques for producing plano, cylindrical, spherical, and aspheric optics.

Task c. Assist and advise in the selection of fabrication processes and their sequencing.

Task d. Recommend process changes to increase quality, improve efficiency, and reduce production costs.

Task e. Identify standard operating and safety procedures of the optics shop and equipment required in the process.

Task f. Document process changes and non-conformances and identify preventative and corrective actions to improve process control.

Critical Work Function 3. Shape and finish bulk materials to generate optical components.

Task a. Determine and perform procedures for measuring, tooling, blocking, generating, shaping, beveling, grinding, polishing, and centering.

Task b. Practice accepted procedure for handling optical materials.

Task c. Apply appropriate procedures for processing a variety of optical materials such as glass, crystals, optical ceramics, and plastics.

Task d. Measure and record dimensionality to ensure adherence to specifications and tolerances.

Task e. Clean, store, secure, document, package, and transport the finished optical components to ensure their integrity and proper identification.

Critical Work Function 4. Operate, maintain, and calibrate optics manufacturing and testing equipment.

Task a. Use proper procedures to operate all machinery from hand beveling wheels to CNC machines.

Task b. Apply accepted standards to maintain work area cleanliness.

Task c. Inspect and maintain equipment, per prescribed schedules, to ensure optimal use and productivity and document these efforts.

Task d. Use the work instruction template to verify set points in the control screens.

Task e. Detect malfunctioning equipment and adjust or repair as necessary and/or notify appropriate work personnel.

Task f. Identify health hazards associated with specific materials and processes and use accepted practices to ensure health of self, others, and the environment.

Critical Work Function 5. Conduct optical metrology measurements and inspections for in-process work and final distribution.

Task a. Coordinate with quality assurance to ensure compliance to design specifications and documentation requirements.

Task b. Participate in the development of inspection plans that use the appropriate metrology for all measured specifications.

Task c. Test finished components by appropriate means including test plate or interferometric techniques to ensure compliance with design specifications.

Task d. Use autocollimators to measure angular error, pyramid error, beam deviation, and dimensional deviations for both in-process and finished products.

Task e. Use collimator or interferometer to measure focal length and on-axis aberrations.

Task f. Inspect surface quality of finished product to comply with appropriate scratch-and-dig standards as specified on the component drawing or specification sheet.

Task g. Measure surface roughness using white light interferometry or other optical means.

Task h. Measure the processed surfaces or components using appropriate equipment (e.g., profilometer, optical comparator, coordinate measuring device, micrometer, or drop gage).

Task i. Determine and select using written instructions and specifications, appropriate packaging for protecting, storing and shipping optics.

Task j. Document final inspection results according to instructions, procedures, and/or specifications to close-out job jacket or equivalent.

Task k. Maintain NIST certified calibration standards and samples, be able to calibrate all optical instruments per proper procedures and maintain a calibration log.

Task l. Use statistical process control guidelines for sampling finished components.

Critical Work Function 6. Assemble optical components and systems (e.g., cemented and air-spaced doublets and triplets).

Task a. Interpret assembly drawings.

Task b. Use proper cleanroom and air-flow workbench procedures.

Task c. Use proper alignment techniques for assembly processes.

Task d. Select and/or use appropriate or required optical adhesives or epoxies.

Task e. Mount optical components in mechanical assemblies using prescribed methods.

Task f. Align and pot elements in cells.

Task g. Measure conformance and performance of optical assembly via mechanical and/or optical means. Determine root cause of any non-conforming assemblies.

Task h. Clean, prepare and inspect optical surfaces prior to assembly per requirements.

Critical Work Function 7. Apply anti-reflectance coatings to optical components.

Task a. Interpret drawing for coating specifications.

Task b. Clean and inspect optics for coating using accepted procedures.

Task c. Load and operate coating equipment to apply thin film coatings using prescribed procedures.

Task d. Operate spectrometer to test coating performance on witness samples and verify results with drawing specifications.

TECHNICAL SKILLS

1. General Proficiencies

- a. Use basic mathematical concepts to include fractions, decimals, ratio, proportion, powers and algebra principles.
 - b. Use and convert metric and English units, and use of scientific notation.
 - c. Use of angle measurements in degrees, radians, minutes, and seconds.
 - d. Apply procedures of geometry and trigonometry to optics.
 - e. Use hand calculators and computers proficiently.
 - f. Operate common machine shop equipment for metals such as lathes, band saws, drill presses, and milling machines.
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2. Planning

- a. Identify the shapes of various optical components and their use in an optical assembly/system.
 - b. Read and interpret technical drawings and specifications.
 - c. Use quality assurance criteria to determine deficiencies in materials and optics using established design specifications.
 - d. Incorporate basic project management strategies in developing production plans.
 - e. Use basic cost estimation techniques to determine cost vs benefit factors.
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3. Material Selection

- a. Determine optical, chemical, thermal and mechanical properties of selected materials from handbooks, supplier specification sheets, and Internet sources, and assess their relevance to specified manufacturing processes.
- b. Apply chemical safety procedures to chosen optical materials and solvents.
- c. Evaluate physical properties of materials for hardness, cleavage, fracturing and chemical stability and assess their relevance to specified manufacturing processes.

- d. Identify physical and environmental hazards associated with various optical materials and the solvents used to process them.
 - e. Measure and analyze homogeneity of materials using interferometry techniques.
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4. Optical Fabrication

- a. Use a loupe to identify bulk material defects such as inclusions, bubbles, striae, and fractures.
 - b. Use polarization measurement techniques to identify internal stress.
 - c. Use appropriate hand tools (e.g., calipers, micrometers, depth gauges, spherometers) during fabrication and inspection of optical components.
 - d. Perform basic CNC controller programming functions according to specifications and assess their performance against established specifications.
 - e. Select appropriate abrasives including grit size and composition to achieve design tolerances and specifications for specific materials.
 - f. Optimize fabrication tools and parameters to increase efficiency and quality.
 - g. Prepare fixtures for mounting starting material as part of the fabrication process.
 - h. Determine the interaction between various materials used in high tolerance optics fabrication such as hot pitch and acetone.
 - i. Operate equipment (e.g., cut-off and wire saw, abrasive grinding machines, and coring machines) to shape optical materials to specifications.
 - j. Operate grinding and polishing machines to generate plano, spherical, aspherical, cylindrical, and toric optics.
 - k. Prepare bevels necessary for suitable optical mounting.
 - l. Inspect finished optical components to ensure compliance with established specifications.
 - m. Use proper procedures in mixing, degassing, applying, and establishing cure times for adhesives and epoxies.
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5. Optics Inspection

- a. Measure deviations from specifications in dimensionality and surface quality and roughness.
 - b. Measure surface quality using appropriate equipment (e.g., scratch-and-dig inspection box, microscope, loupe, and magnifiers).
 - c. Measure surface roughness with appropriate equipment (e.g., white light interferometer, laser surface profiler).
 - d. Measure shapes using appropriate equipment (e.g., profilometers or coordinate measuring devices), and determine deviations from specifications in dimensionality.
 - e. Use quality assurance criteria to determine deficiencies in materials and optics using established design specifications.
 - f. Measure angular errors with appropriate equipment (e.g., autocollimators or interferometers)
 - g. Inspect materials using birefringence testing via polarimeters and index of refraction testing.
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6. Clean Room and Assembly

- a. Use established procedures for personnel gowning for cleanroom operations, including booties and beards.
- b. Use proper procedures for entering and exiting air locks and door locks in a clean room facility.
- c. Interpret clean room Class Ratings required in optics fabrication (e.g., Class 100, 1000, and 10,000).
- d. Monitor air flow filtration, room pressure, air velocities, temperature and relative humidity of clean rooms.
- e. Clean optics to specifications using proper techniques.
- f. Store optics in appropriate container with environmental controls.
- g. Measure optical properties using appropriate equipment (e.g., autocollimators).

- h. Align physical and optical centers following specifications.
 - i. Inspect finished products following accepted procedures to ensure compliance with established specifications.
 - j. Evaluate shipping conditions for finished optics to determine appropriate packaging.
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7. Thin Film Coatings

- a. Identify the function of antireflection and protective thin film coatings on optical surfaces.
 - b. Prepare optics for thin film coatings by cleaning optical surfaces requiring a coating.
 - c. Interpret drawings for coating specifications to determine proper coating materials.
 - d. Operate vacuum systems used for coating optics.
 - e. Use fixtures for mounting optics in coating chambers.
 - f. Select appropriate coating procedures and operate coating equipment.
 - g. Use proper sensors to monitor film properties during coating processes.
 - h. Operate spectrometer to test coatings on witness sample.
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8. Maintenance and Tooling

- a. Apply appropriate maintenance instructions from manufacturers equipment manuals.
- b. Maintain and prepare pumps and conduits to properly deliver slurry and coolant to work surfaces.

EMPLOYABILITY SKILLS

1. Read Instructions (in English) and follow established procedures.
2. Present in English technical information clearly and concisely in written and oral form.
3. Manage and communicate time schedules and schedule changes.
4. Use materials and resources efficiently.
5. Use hand calculators and computers as tools for enhancing the quality and efficiency of performing assigned tasks.
6. Maintain updated and relevant tracking data on parts and support materials distribution systems.
7. Establish and maintain effective working relationships with others involved in the processing and fabrication of materials and parts.
8. Identify and assimilate information from prior shifts to determine process status on parts.
9. Perform problem solving by standard techniques of analysis using the scientific method.
10. Work responsibly with minimum supervision.
11. Work cooperatively with others.
12. Follow established safety rules and regulations.
13. Exercise good judgment in quickly and accurately reporting accidents and equipment malfunctions.
14. Navigate the Internet to gather information.
15. Meet established schedules for work days, assignments, and tasks.
16. Evaluate graphical and tabular data.
17. Maintain a daily laboratory notebook.
18. Create and implement system-schedule maintenance plans.
19. Seek a high level of detail in pursuing all assigned tasks.