# Production and Characterization of Optics and Coatings with Extremely Low Losses and High Reflectivity

Ramin Lalezari and Howard Champoux

*FiveNine Optics, Inc., Boulder CO*

*Corresponding e-mail address: ramin@fivenineoptics.com, howard@fivenineoptics.com*

**Low loss optics have been produced for several decades and used in a variety of applications including inertial navigation, gravitational wave detection, precision spectroscopy, atomic clocks and high power and high energy lasers. Ion beam sputtered coatings on super polished substrates allow for the realization of extremely low levels of absorption and scatter (in the range of a few parts per million) in the visible and near infrared portion of the spectrum.**

## ION BEAM SPUTTERED OPTICAL COATINGS

Ion beam sputtering is a physical vapor deposition where a beam of ions is accelerated electrically to impinge on a target of high purity material causing molecules of the material to be sputtered from the target and deposited on a substrate. The process was developed and patented in the early 1970s by David Wei and Anthony Lauderback [1].

In the 1970s and 1980s the process was used primarily by the manufacturers of ring laser gyroscopes for its ability to produce dielectric mirrors with very low levels of scatter. The very low deposition rates of the early equipment and the cost and difficulty of use of the deposition equipment prevented early broad proliferation of the process. By the mid 1990s the advent of wavelength division multiplexing and the enormous investment in fiber-optics telecommunications industry drove the commercialization of ion beam sputtering and its broader use in the manufacture of optical coatings. The availability of low loss optical coatings have enabled a number of scientific, industrial, and military applications. Gravitational wave detection, development of atomic clocks, the development of laser weapons, and a variety of spectroscopy applications are all enabled by low loss optical coatings and mirrors. Mirror coatings with losses of less than 10 ppm are routinely produced with current ion beam sputtering technology.

## SUPER POLISHED SUBSTRATES

Realization of low scatter optical coatings requires substrates with very low roughness in optical spatial frequencies [2]. Polishing techniques and instrumentation for evaluating the substrates were also developed in the 1970s and 1980s by the inertial navigation industries and continue to benefit from materials development in the semiconductor industry. Today substrates with less than 1 angstrom rms roughness for optical spatial frequencies suitable for supporting mirrors with less than 1 ppm of scatter are commercially and broadly available.

## DESIGN CONSIDATIONS AND CHARACTERISTICS OF LOW LOSS MIRRORS AND OPTICS.

Manufacturing technologies and performance characteristics of optics with PPM levels of loss will be presented. Design considerations for applications such as photon pressure power meters, and other large low loss mirrors as well as stress [3], polarization, and laser damage threshold issues will be discussed.

## REFERENCES

1. D. Wei and A. Louderback , US Patent # 4,142,958 “Method for Fabricating Multilayer Optical Coatings”, 1979
2. J. M.Bennett and L. Mattsson, “Introduction to Surface Roughness and Scattering” (Optical Society of America, Washington DC, 1989)
3. Stoney G, “The tension of metallic films deposited by electrolysis”, Proc. Royal Soc. London, A82 (1909) 172