Comparison of Absolute Measurements of Laser Power Using Next Generation NIST High Power Radiometer and Air Force High Power Calorimeter

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We report comparisons of laser power measurements between the new NIST radiometer, also known as the BB Prime, and the current Air Force standards, known as the BB calorimeter. [1] These measurements were performed by use of high power laser sources in the Air Force's Laser Hardened Materials Evaluation Laboratory

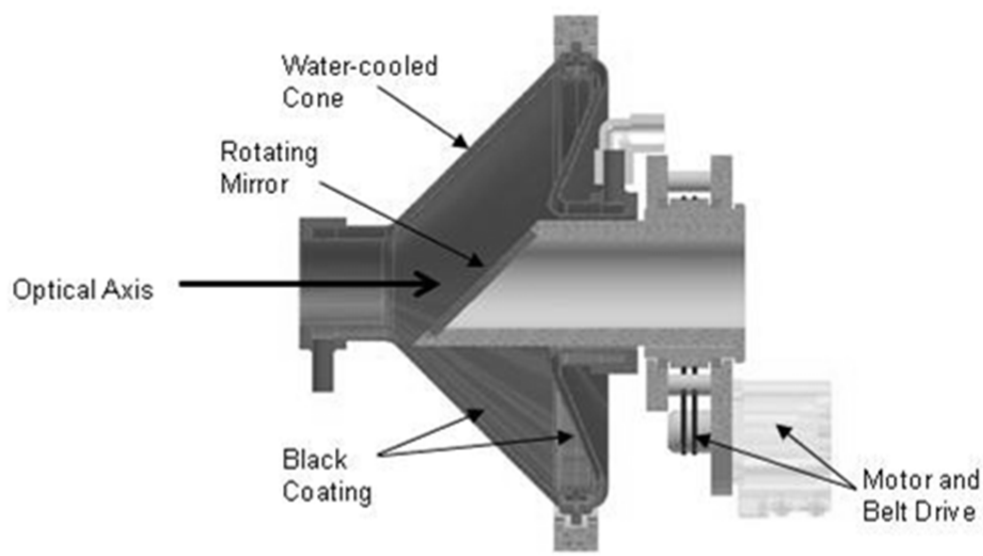

Figure 1. BB Prime Cavity cross section view. Laser radiation enters the cavity from the left along the optical axis. There is a 45° angle of incidence between collimated laser radiation entering the cavity and the rotating mirror at the back of the cavity. The rotating mirror spreads the incoming laser radiation within a light-trapping cavity coated with a novel black absorber. The cavity consists of 45° front and 22.5° rear water-cooled cones that trap the laser radiation inside the cavity. The black absorber has a damage threshold of approximately 15 kW/cm^2.

DESIGN

There is a dearth of stable, accurate power meters for use with lasers capable of power densities in the range of 10 kW/cm^2. These types of lasers are generally used in laser cutting and/or welding applications as well as military applications. With Air Force support, NIST has developed a next generation high-power laser calorimeter (BB Prime) for laser power measurements up to the 100 kW level with lower uncertainties than existing standards. The BB Prime power meter was designed to measure laser power in the 50 W to 100 kW range with a 1 % expanded uncertainty.

The BB Prime consists of an optical cavity (see Figure 1) and portable, modular components with a framework based on custom shipping containers, which can be set up in less than a day. The BB Prime design has several innovative features – scalable to very high laser powers (from 50 W to 100 kW), novel NIST-developed black coatings with damage thresholds of approximately 15 kW/cm^2, [2] and a novel water-cooled absorber reducing measurement period by a factor of 100. Photographs of the black coating, BB Prime, and its components are shown in Figure 2. The details of the black coating are described elsewhere. [2]

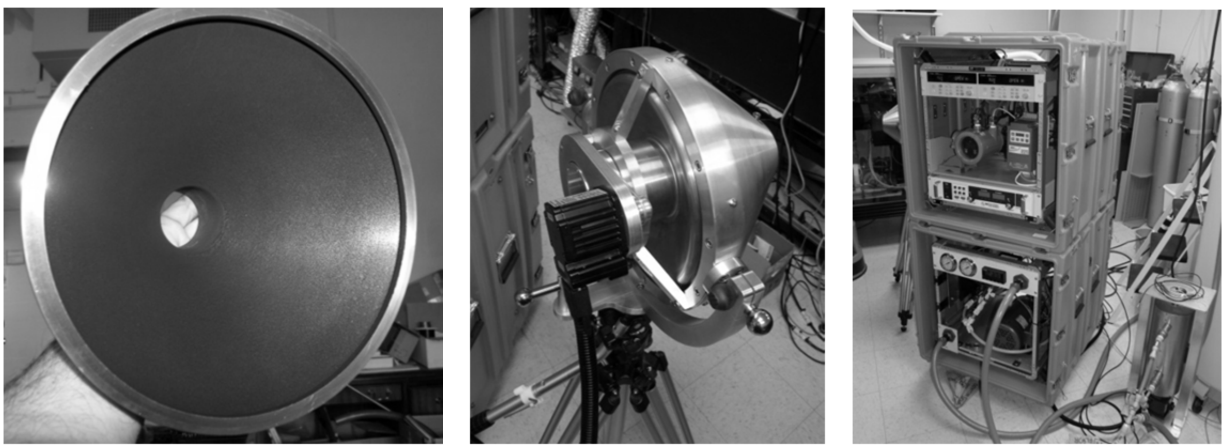

Figure 2. Inside of the optical cavity showing the black coating (left), front view of the BB Prime (center), and portable, modular control equipment (right).

Wavelength (μm)	Injection Period (s)	Power (W)	BB Energy (J)	BB Prime Energy (J)	Ratio
10.6	3.1	3966	12294	12236	1.0048
10.6	3.1	4011	12434	12520	0.9932
1.07	20.1	896	18013	17936	1.0043
1.07	20.1	2705	54318	53729	1.0110
1.07	20.3	4390	89206	88237	1.0110

Table 1. Comparison of laser energy measurement results from NIST BB Prime and Air Force BB calorimeters. Wavelength and Power refer to the laser wavelength and power, respectively. Injection Period represents the period during which laser power was deposited into the calorimeter. The Ratio is the measured value of the BB Energy divided by the measured value of the BB Prime Energy for a given wavelength, power, and injection period.

RESULTS

Comparisons of laser energy measurements using the BB Prime and the existing Air Force BB standards [1] at the Air Force's Laser Hardened Materials Evaluation Laboratory resulted in excellent agreement. These comparisons were performed at a laser power of approximately 4 kW and laser wavelengths of 1.07 μm and 10.6 μm. The resulting ratio between the two standards was 1.0048 with a standard deviation of 0.73 %. See Table 1 for a list of measured ratios as a function of laser wavelength and power.

REFERENCES

[1] R.L. Smith, T.W. Russell, W.E. Case, and A.L. Rasmussen "A Calorimeter for High-Power CW Lasers," *IEEE Trans Instrum Meas* **IM-21** (1972).

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