CALIFORNIA STATE SCIENCE FAIR
2017 PROJECT SUMMARY

Name(s)

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Project Number

S1817

Project Title

Measuring Planck's Constant: Adventures in Watt Balance Land

Abstract

Objectives/Goals

Significantly reduce the measurement uncertainty for Plancks constant h attainable on a home-built watt balance by optimizing the laser detection system.

Methods/Materials

Inspired by the work of the mass metrology team at NIST, a fully functional watt balance instrument has been constructed. Custom coils were wound, a knife-edge main bearing was machined, electronics for detection and control were built. A floating battery powered supply was built to provide reverse bias on the photodiode detector, allowing higher intensity lasers to be evaluated. Four different lasers were evaluated for best performance in the shadow sensor detection system. The watt balance approach compares measurements made in force mode (static balance) and velocity mode. For a given system configuration, a measurement of h involved: calibrating the shadow sensor; n=10 replicate measurements of BLv in velocity mode and BLf in force mode. For force mode, 0-A-0 and A-B-A type measurements were compared.

Results

A baseline was established by measuring Plancks constant h with the system in stock configuration:
h = 6.67 E-34 J s, precision 0.3%, accuracy 0.7%, uncertainty 0.7%.
Uncertainty arising from the shadow sensor response was clearly the limiting factor in overall measurement uncertainty for h.
Lasers for the shadow sensors were evaluated for sensitivity, linearity, beam profile, noise and drift. The best overall performance was achieved with a raw laser diode with no focusing optics. The calibration of the shadow sensor was compared with a simple numerical model for the diode laser Gaussian beam profile, with a 3rd order polynomial giving the best fit.
With all improvements in place final results attained were:
h = 6.64 E-34 J s, precision 0.2%, accuracy 0.2%, uncertainty 0.25%.

Conclusions/Discussion

A home-built watt balance apparatus to measure Plancks constant h has been constructed and refined. Multiple system enhancements (knife-edge bearings, alignment, shrouding) helped with reliable operation, and improvements to the shadow sensor (optimum laser, floating bias supply, cubic calibration fit) improved the overall measurement uncertainty for h by almost x4.

Summary Statement

Measurement uncertainty for h was improved by almost x4 relative to NISTs published value for a home-built system, refining the shadow sensor response was the major factor in this improvement.

Help Received

Thanks to my dad for subsidizing the necessary materials, helping me with the data acquisition and the poster graphics. Thanks to Gramps for gifting me the data logger and the voltage reference.