Spring 5-23-2018

Automating Knife-Edge Method of THz Beam Characterization

Christopher Charles Faber
Portland State University

Automating the Knife-Edge Method of THz Beam Characterization

By Chuck Faber, Ha Tran, Thanh Le, and Dr. Branimir Pejcinovic

Department of Electrical and Computer Engineering, Portland State University

Introduction

Commercial solutions for THz beam profiling are not widely offered or prohibitively expensive.

In this project I aim to develop a cheap solution using widely available hardware and software.

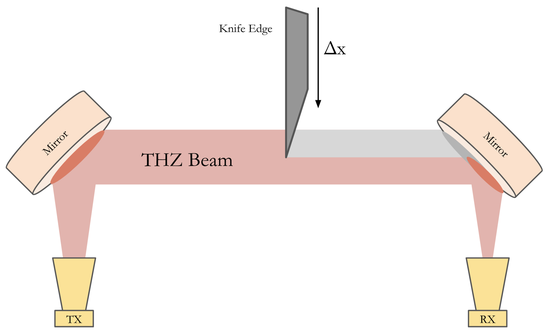

Fig. 1: Beam profiling ideally occurs across collimated or focused beam segment

Our lab measures the frequency response (absorption and reflection) of various materials to sub-THz radiation. To collect reliable data, the ideal beam should have a gaussian beam profile.

The ideal profile of the beam along an axis x can be described by Eq. (1), where w is the $1/e^2$ beam waist. [2]

$$I(x) = I_0 \cdot exp[\frac{-2x^2}{w^2}] \quad (1)$$

Knife Edge Method of Beam Profiling

The knife-edge method of beam profiling involves translating an edge across beam and measuring the S21 transmission parameter in successive steps *(fig. 1)*. The transmission data must be differentiated to obtain the modal profile of the beam. *(fig. 6)*

Using this method manually is a time-intensive process. The aim of this project is to develop a cheap, fast, and reliable system for beam profiling.

System Features and Experimental Setup

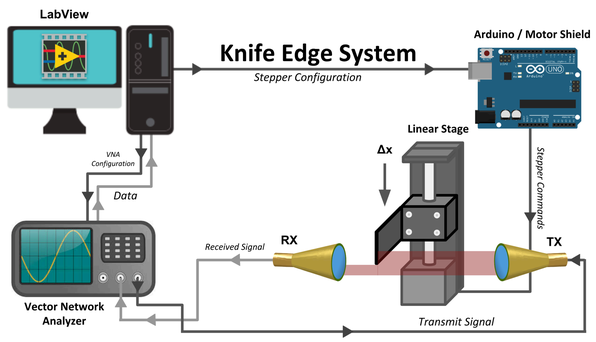

Fig. 2: Automated Knife Edge System Schematic

System Features

- Controlled via custom LabView program (VI).
- Communicates with Arduino/Motor Shield.
- Controls a stepper motor translating the knife-edge stage.

UI Interface

- VI collects S21 data from VNA in between each step and plots in real time.
- VI configures the step resolution, step speed, and total number of steps.

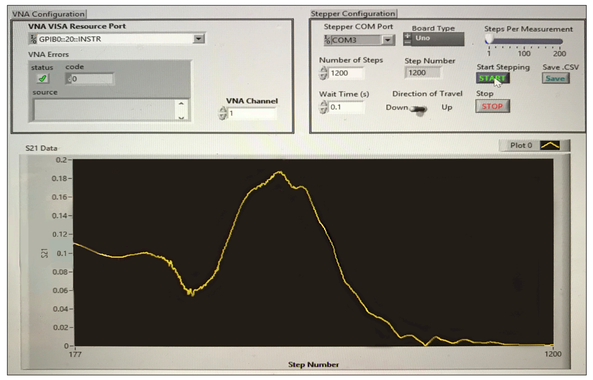

Fig. 3: Labview program front-end.

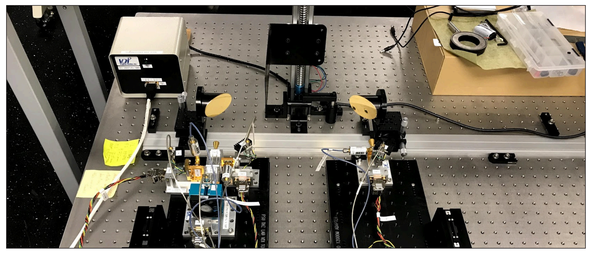

Fig. 4: Optical Set-Up for Collimated THz Beam

Collimated Experimental Setup

- Optical setup uses two parabolic mirrors to collimate the THz signal.
- The knife edge operates in the collimated beam segment.

Non-Collimated Setup

- TX antenna and RX antenna rotated to point directly at each other.
- Does not measure full beam signal.

Results

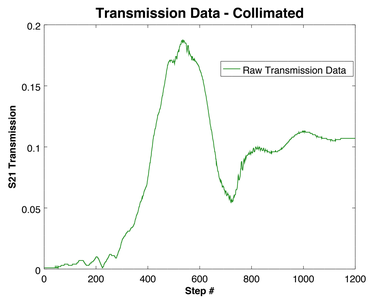

Fig. 5: Collimated Beam Raw Abberant Transmission Data. Plots generated in Octave.

Collimated Beam Data *(fig. 5)*

- Increase in transmission as the knife edge approaches the THz beam.
- Reflections from beam dispersion
- Poor vertical collimation.

Non-collimated Beam Data

- Noise greatly reduced but still present in small amounts. *(fig. 6)*

Curve Fitting

Transmitted power along a transverse axis x is described by Eq. (2).[1] Curve is fit using the `normcdf()` function in Octave [Eq. (3)] and derived for approx. intensity profile.

$$P_N(x) = \frac{1}{2}[1 \pm erf(\frac{x - x_0}{w})] \quad (2)$$

$$normcdf(x) = \frac{1}{2}[1 - erf(-\frac{x}{\sqrt{2}})] \quad (3)$$

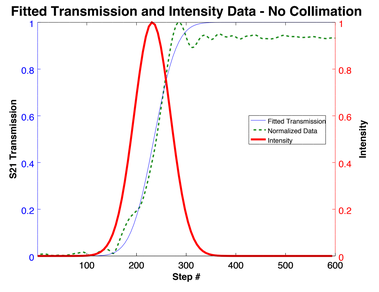

Fig. 6: Raw data from non-collimated set-up fit to normalized cumulative distribution function and derived intensity profile

Conclusions

The system generally operates as expected. Data is collected faster and has better resolution than manual data collection by an approximate factor of 10. Total cost was $170.

Next Steps

- Install sharper knife edge to reduce reflection and diffraction effects.
- Test alternate fit algorithms.
- Improve user-friendliness of curve fitting script.

References

[1] M. Araújo, R. Silva, E. Lima, D. Pereira, and P. Oliveira, "Measurement of Gaussian laser beam radius using the knife-edge technique: improvement on data analysis," Appl Optics, vol. 48, no. 2, p. 393, 2009.

[2] J. Magnes, D. Odera, J. Hartke, M. Fountain, L. Florence, and V. Davis, "Quantitative and Qualitative Study of Gaussian Beam Visualization Techniques," arXiv, 2006.

Contact Information:

Chuck Faber
Email: cfaber@pdx.edu

Dr. Branimir Pejcinovic
Email: pejcinb@pdx.edu

Sponsorship:

The authors acknowledge the support of the Semiconductor Research Corporation (SRC) Education Alliance (award # 2009-UR-2032G) and of the Maseeh College of Engineering and Computer Science (MCECS) through the Undergraduate Research and Mentoring Program (URMP)

Semiconductor Research Corporation

Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY