MICRO AND NANO FABRICATION OF TERAHERTZ WAVEGUIDE COMPONENTS

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MICRO AND NANO FABRICATION OF TERAHERTZ WAVEGUIDE COMPONENTS

by

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Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy

to the

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This thesis work is dedicated to

My Parents, Family and Friends

CERTIFICATE

I hereby certify that the dissertation entitled **"MICRO AND NANO FABRICATION OF TERAHERTZ WAVEGUIDE COMPONENTS"** submitted by **Mr. Rakesh Kumar Bhardwaj** in fulfillment of the award of **Doctor of Philosophy** in Mechanical Engineering Department of the Indian Institute of Technology Delhi is an authentic record of the investigations carried out by him under my guidance and supervision. The presented work has fulfilled the requirement for the submission of this thesis and has reached the required criterion to the best of my knowledge and belief.

The research work has not been submitted previously for the award of any degree of any other university.

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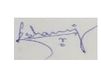

Abstract

The demand of high-speed wireless communication has increased, which need the data rate of the order of Terabyte per second (Tbps) in near future. Terahertz (THz) band communication is a key wireless communication technology to satisfy this future demand. This will also reduce the spectrum scarcity and capacity limitation of current wireless systems. Micro fabricated folded waveguides are potential compact source of wide band and high-power terahertz radiation.

This study primarily focuses on machining technology for THz waveguide components requiring ultra-high precision micro machining. Rectangular waveguides especially folded waveguides are even more difficult to manufacture using conventional machining techniques due to their small size and very tight tolerances. The criticalities in micromachining of Terahertz waveguide Components staring from 100GHz to 1100 GHz been developed mechanically in this research work. Free cutting Brass IS 319-H_2 and AL Alloy IS:736 24345 WP were used as work materials due to its electrical and mechanical properties. Waveguide size as small as 0.254x0.127 mm (254x127 µm) was micro machined within ±3-5 µm linear tolerances, surface roughness of the order of 0.045 µm Ra and flatness less than 0.3 µm ($< \lambda/2$). The split top and bottom blocks of the waveguide were aligned by dowel pins which matched within a tolerance of ± 5 µm. The perpendicularity and parallelism were maintained within ±5 µm tolerance as per IS:8000, 1975. This work explored and established the application of micro milling as reasonably suitable for the THz waveguides followed by ultrasonic cleaning. Waveguide above 1.1 THz having waveguide size as small as 75µmx 37.5µm were also realized using femto second LASER within nanometer level accuracies. Measurements of folded waveguide at 0.22THz waveguide losses were close to simulated values.

Keywords: Terahertz (THz); Waveguide; folded waveguide; Linear Tolerance; Surface roughness; Micromachining; Femto second Laser; S-Parameters; Geometrical Tolerances; Lapping; Dowel Pin.

सार

हाई-स्पीड वायरलेस कम्युनिकेशन की मांग बढ़ गई है, जिसे निकट भविष्य में टेराबाइट प्रति सेकंड (Tbps) के ऑर्डर की डेटा दर की आवश्यकता है। टेराहर्ट्ज (THz) बैंड संचार भविष्य की इस मांग को पूरा करने के लिए एक प्रमुख वायरलेस संचार तकनीक है। यह स्पेक्ट्रम की कमी और मौजूदा वायरलेस सिस्टम की क्षमता सीमा को भी कम करेगा। माइक्रो फैब्रिकेटेड फोल्डेड वेवगाइड वाइड बैंड और हाई-पावर टेराहर्ट्ज विकिरण के संभावित कॉम्पैक्ट स्रोत हैं।

यह अध्ययन मुख्य रूप से अल्ट्रा-उच्च परिशुद्धता माइक्रो मशीनिंग की आवश्यकता वाले THz वेवगाइड घटकों के लिए मशीनिंग तकनीक पर केंद्रित है। आयताकार वेवगाइड विशेष रूप से मुड़े हुए वेवगाइड अपने छोटे आकार और बहुत सख्त सहनशीलता के कारण पारंपरिक मशीनिंग तकनीकों का उपयोग करके निर्माण करना और भी कठिन होता है। इस शोध कार्य में १०० गीगाहर्ट्ज़ से ११०० गीगाहर्ट्ज़ तक के टेराहर्ट्ज़ वेवगाइड घटकों के माइक्रोमशीनिंग में महत्वपूर्णताओं को यांत्रिक रूप से विकसित किया गया है। फ्री कटिंग ब्रास IS 319-H2 और AL अलॉय IS:736 24345 WP को इसके विद्युत और यांत्रिक गुणों के कारण कार्य सामग्री के रूप में उपयोग किया गया था। वेवगाइड का आकार 0.254x0.127 मिमी जितना छोटा था, ± 3-5 माइक्रोन रैखिक सहिष्णुता, 45 नैनो मीटर Ra के क्रम की सतह खुरदरापन और 0.3 μm (<λ/2) से कम समतलता के भीतर सूक्ष्म मशीनीकृत था। वेवगाइड के विभाजित शीर्ष और निचले ब्लॉक को डॉवेल पिन द्वारा संरेखित किया गया था जो ± 5 माइक्रोन की सहनशीलता के भीतर मेल खाता था। लंबवतता और समानता को IS:8000, 1975 के अनुसार ± 5 माइक्रोन सहिष्णुता के भीतर बनाए रखा गया था। इस कार्य ने माइक्रो मिलिंग के अनुप्रयोग को टेराहर्ट्ज वेवगाइड के लिए उपयुक्त रूप से उपयुक्त के रूप में खोजा और स्थापित किया जिसके बाद अल्ट्रासोनिक सफाई हुई। 1.1 THz से ऊपर के वेवगाइड, जिनका वेवगाइड आकार 75μm x 37.5μm जितना छोटा है, को नैनोमीटर स्तर की सटीकता के भीतर फेम्टो सेकंड लेजर का उपयोग करके महसूस किया गया। 0.22 THz फोल्डेड वेवगाइड की माप सिमुलेटेड मूल्यों के करीब थी।

कीवर्ड: टेराहर्ट्ज़ (THz); वेवगाइड; मुड़ा हुआ वेवगाइड; रैखिक सहिष्णुता; सतह खुरदरापन; सूक्ष्म मशीनिंग; फेम्टो सेकेंड लेजर; एस-पैरामीटर; ज्यामितीय सहिष्णुता; लैपिंग; मेख पिन

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