Dedicated to
Pandit Madan Mohan Malaviya
Ji,
My Parents
&
My husband

Undertaking

I, Gargi Dixit, certify that the work embodies in this Ph.D. thesis is my own bonafide work carried out by me under the supervision of Prof. P.K.Jain from July 2011 to July 2016 in the Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University). The matter embodies in this Ph.D. thesis has not been submitted for the award of any other degree/diploma.

Gargi

(Gargi Dixit)

DECLARATION BY THE CANDIDATE

I, "**Gargi Dixit**", certify that the work embodied in this Ph. D. thesis is my own bonafide work carried out by me under the supervision of "**Prof. P. K. Jain**" from "**JULY 2011 to JULY 2016**" at "**DEPARTMENT OF ELECTRONICS ENGINEERING**", Indian Institute of Technology (Banaras Hindu University). The matter embodied in this Ph. D. thesis has not been submitted for the award of any other degree/diploma.

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P.K. Jain 16/7/2016

Dr. P. K. Jain, Professor
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It is certified that the work contained in the thesis titled, **"Equivalent Circuit Approach to the Beam-Wave Interaction Analysis of the Magnetically Insulated Line Oscillator,"** by Ms. Gargi Dixit, has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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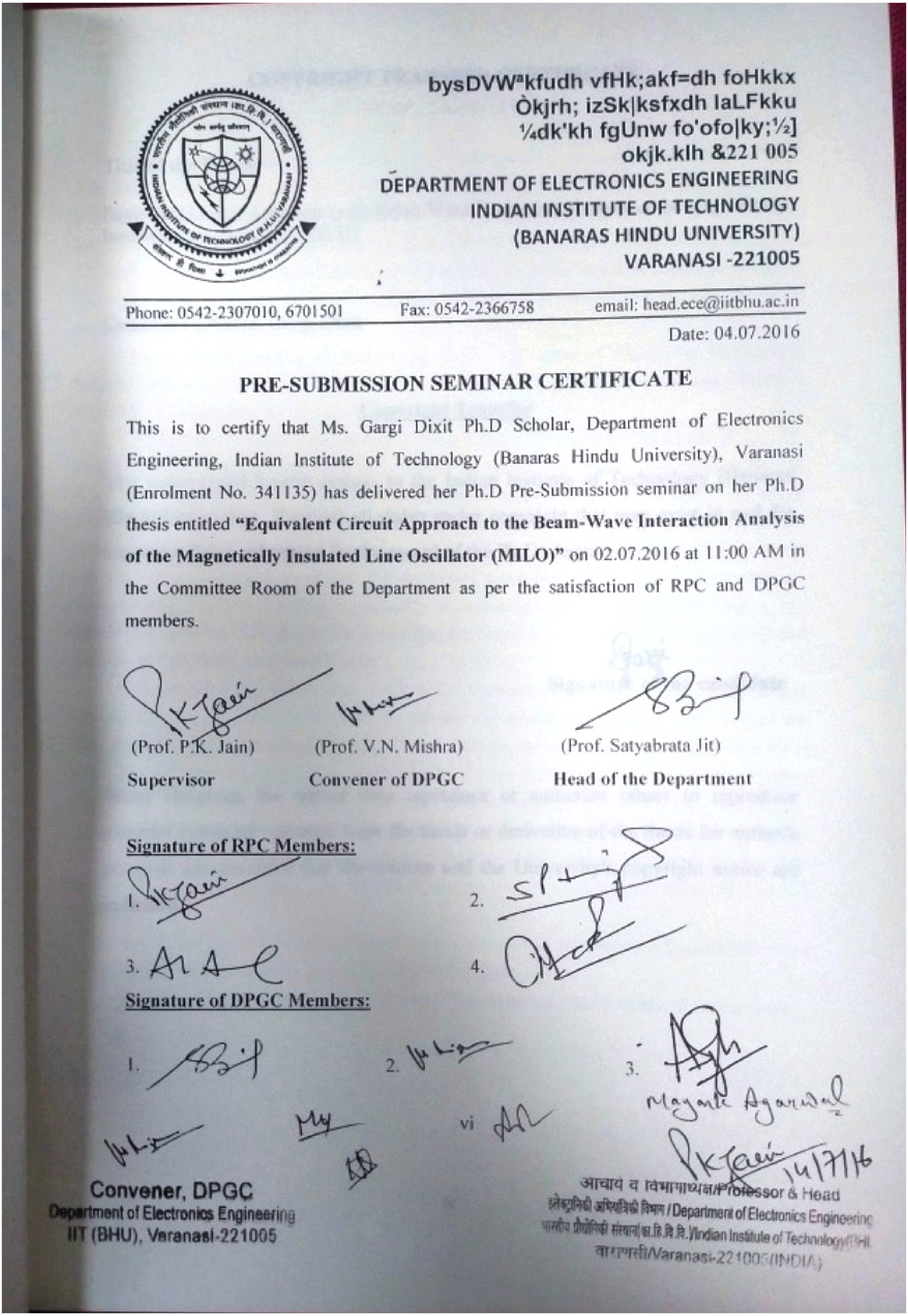

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PK Jain

(Prof. P.K. Jain) (Prof. V.N. Mishra) (Prof. Satyabrata Jit)

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Date: 16-7-16

Gargi

(Gargi Dixit)

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

γ	Relativistic factor
α	Coupling coefficient of cavity
r_w	Waveguide Radius
r_b	Beam radius
r_c	Cathode radius
v_d	Drift velocity of electrons
v_p	Phase velocity of RF wave
ω_p	Plasma frequency
ω_c	Cyclotron frequency
c	Velocity of light in free space
e	Electron charge
m_e	Mass of electron
B_{cr}	Critical magnetic field
B_θ	Azimuthal self magnetic field
I_{cr}	Critical current
I_0	Start-oscillation current
ω	Angular frequency of the RF wave
s	Strength of EM wave
n	Space harmonic of travelling wave
m	Modal harmonic
Jm_0	m^{th} order ordinary Bessel function of first kind
L	Periodicity between discs
T	Thickness of discs
θ, r, z	Azimuthal, radial, and axial cylindrical coordinates
k_0	Free-space propagation constant
ψ	Perturbation parameter
h_0	Mode wave number

ω	Angular frequency
ς_n	Velocity shifted frequency
γ_n	Perturbed relativistic momentum
$x_{m,n}$	Eigen value(root of Bessel function)
r_{a1}	Choke cavity radius
r_{a3}	Extractor cavity radius
Z_f	Flow impedance parameter
Z_o	Load impedance
Z_r	Impedance at magnetically insulated sheath
θ	Transit angle
η_{elec}	Conversion efficiency
d	Axial depth of collector cavity
L_c	Length of collector
C_e	Shunt capacitance per unit length
L_e	Series inductance per unit length
β_n^I	Axial propagation constant in region *I*
γ_n^I	Radial propagation parameter
k	Free space propagation constant
H_θ	Azimuthal component of magnetic field intensity
ρ_s	Surface charge density
V	Scalar Potential
A_z	Vector potential
m	Modal Harmonic
β_m^{II}	Axial propagation constant in region *II*
J_{z1}	perturbed (RF) axial current density
$f_1\{x,p,t\}$	RF distribution function
E_z^I	Axial electric field intensity in region *I*
E_r^I	Radial electric field intensity in region *I*

H_θ^I	Azimuthal magnetic field intensity in region *I*
j	Square root of -1 (that is, $\sqrt{-1}$)
J_0	Zeroth –order Bessel function of the first kind
J_0'	Derivative of the zeroth –order Bessel function of the first kind with respect to argument
A_0^I	Fundamental space-harmonic field constant in region *I*
A_0^{II}	Fundamental space-harmonic field constant in region *II*
A_n^I	n^{th} space-harmonic field constant in region *I*
A_m^{II}	m^{th} stationary-wave modal harmonic field constant in region *II*
A_m^{III}	m^{th} stationary-wave modal harmonic field constant in region *III*
$A_{m,b}^{II}$	m^{th} stationary-wave modal harmonic field constant referring to the backward wave component in region *II*
$A_{m,b}^{III}$	m^{th} stationary-wave modal harmonic field constant referring to the backward wave component in region *III*
$A_{m,f}^{II}$	m^{th} stationary-wave modal harmonic field constant referring to the forward wave component in region *II*
$A_{m,f}^{III}$	m^{th} stationary-wave modal harmonic field constant referring to the forward wave component in region *III*
$B_{m,f}^{II}$	m^{th} stationary-wave modal harmonic field constant referring to the forward wave component in region *II*
$B_{m,b}^{II}$	m^{th} stationary-wave modal harmonic field constant referring to the forward wave component in region *II*
$M_{n,m}$	Dimensionless function involving propagation constant sand structure parameters
$N_{n,m}$	Dimensionless function involving propagation constant sand structure parameters
$\det\lvert M_{n,m}-N_{n,m}\rvert$	Dispersion relation

PREFACE

High Power Microwaves (HPM) has drawn considerable attention in recent years as a new technology, allowing new strategic-applications and offering innovative approaches to existing applications. Many of the HPM sources are being developed are derivatives of sources that are well known to the vacuum electronics community. HPM sources are being developed that provide peak powers that exceed 1GW at frequencies on the order of 1GHz in short pulses, typically on the order of 100ns. The technology that is used to drive such sources has its root in pulsed power and a comprehensive understanding of their behavior requires the use of tools that have been developed in the plasma physics community. Magnetically Insulated Line Oscillator (MILO) is one of the most stimulating device among all the cross field device family and has been now extrapolated to the high pulsed power microwave regime in the range of gigawatts. MILO is a compact, robust, and simple device which does not require external DC magnetic field for its operation.

MILO is basically a linear variant of the magnetron invented by M. Collins Clark during 1988 at Sandia National Laboratory, USA. It is a high power microwave source capable of delivering output power greater than 1GW at a frequency of 1-10GHz. Because high power microwave sources operating in gigawatt range of pulse length of ~ 100 ns to 1 µsec has applications in defense and plasma systems, there are continued interest in improving the output performance of the MILO which includes RF output power, pulse length, efficiency, cathode performance, and power extraction.

Initial research and development work on the magnetron was mainly concentrated at France, China and US, but with growing applications of this device, several other groups around the globe have also emerged out. In India, DRDO, Bangalore is indigenously putting its effort in the research and development of the MILO.

In the present thesis, studies have been made to improve and optimize RF interaction structure of MILO using equivalent circuit approach. This analysis is carried out both for the beam absent and present case for the disc-loaded coaxial waveguide structure. MILO structure has also been simulated using CST-PIC simulation technique. The results have been validated with the experimental data available in different literatures. Further, in order to improve the device power conversion efficiency different improvement techniques have been proposed and validated through the PIC simulation.