Photonic crystal fiber isafuture paradigmin the field of medicalScience

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ABSTRACT

The present communication presents a noteworthy application pertaining to biomedical application relatedtothegenerationof16typesofdifferentlaserbeamwhichhasbeenapplying invariousmedical operationsnow-a-days.The said laser beamshavebeencreatedwith the helpof single photonic structure where photonic structuredealswith the plasmonic basedphotonic crystalfiber (PCF) withhaving5×5 periodicair holeswithdefectatcentre.Theprinciple ofgenerationof surgical laser beamsreliesonboth physicsandmathematicsofphotoniccrystalfiberinsuchway thatphysicsdealswithstructureand configurationofproposedPCF including latticespacinganddiameterofairholeswhere mathematics manipulateswithplane wave expansionmethodtofindouttheelectric fielddistribution inthe fiber. Finallytheoutcomes of the works disclosesthatsuitableconfigurationofplasmonicstructure with respecttogreensignalgeneratesdifferenttypeof laser beamswhichcouldbe usedforbio-medical application.

Keywords:Photoniccrystalfiber;biomedicallaser;plasmonicmaterial;planewaveexpansionmethod

I. INTRODUCTION

Neverthelesstheresearchonscienceandtechnology isburgeoninginhasty mannernow-a-days, researchrelatedtomedicalfieldneedstoimproveinswiftmannertosolveoutvariousproblemsforthenecessityofsociety.Toenvisagethesame,thefieldofelectronicsvisàvisbiotechnologyandbiosciencehavebeenfocused bytheresearchersfrombothgovernmentandnongovernmentsectors.Againconsideringthemedicaldiagnosis,thefieldofoptoelectronicsandlasertechnologyrevolutionisestheinvestigationofdiagnosisandclinicalmedicine.Furthermovingtolaserbasedlightwavetechnology,itbringscontactfreeandkeeplittleimpactintheintegrityoflivingmatter,whichcaneasilybedeployedformedicaloperation[1].Furthermoretheadvancedopticaltechnologysuchasfemtosecondlaserhavebeenusednow-adaystodetectandmonitorthecellularbiochemistry,integrity oforgansand characterizes the tissues.Moreover theopticaltagshave beenused to make the label DNAcellsand the propertiesofblood.Againthehi-techlasertechnology havebeendeployednow-a-daystomakethe diagnosis the structure ofretina andoptic nerveofhumanbody. Apartfromthistheopticalcoherencetomographieshavebeenemployedinmedicalsciencetodetectthepreciseinformationofretinavesselanditspigmentsofepitheliumandchoroidsetc.Furthermorethephotonicswithendoscopicaltechnology evaluatesthedysfunctionofswallowing andphantom.Asidethis, lasertechnology havebeen extensively usedforthesakeofmedicaltherapy andoperationtominimize thecomplication.Torealisethe above said medicaldiagnosisand medicaloperation, the differenttypesof laser beamssuchasgas laser(excimerArF,ArCl, XeCl,XeF),solidstatelaser(KTP/Nd:YAG,Ruby,Alexandrite,Te: sapphire,Ho:YAG,Er:YAG),semiconductor laser (GaAs) anfree electron laser have beengenerated in thisresearch. Asfar as the applicationsof above said laserisconcerned,gaslasers dealswith themany surgicalapplicationsrelated toionizesmoleculeintissues, ophthalmologyandUVradiationsetc.Similarlysolidstatelaserisconcerned,itdealswithmedicalapplications relatedtohumanskin, ophthalmologist(retina),controlling of haemoglobin,removal oftattoosandhairfollicles, urology, pulgronology,gastroenterology andimplanttreatmentetchavebeenmadeusing theaforementioned laser. Beside this, different types of bio-medical applications such as ablation of tissues in ophthalmology,woundhealingandnuro-surgeryetc[2].Tounderstandthesamelucidly,thecurrent paperdisclosesafigure1,whichexplainsthewavelengthanditsapplicationsoftheaforementioned lasers; Keepingtheimportanceofabovesaidapplicationsthepresentpaperpresentsthe methodof generation of such kindof laserswith the helpof singlephotonic structure whichdealswith photonic crystalfiber .Further thecurrentworks isorganisedasfollows;section 2 emphasiseson the structure of photonic crystalfiber and the principle of generationsof the signals. Similarly, the resultand interpretationisdivulgedinsection3 andconclusionsaredisclosedinsection4.

II. 2.STRUCTUREOF PROPOSEDPCFANDGENERATIONOF LASERBEAM

The proposedstructurein thiswork isa twodimensionalphotonic crystalfiber is made of plasmonicmaterial substratehaving5×5airholeswithdefect(noappearanceofairholes) atcentre,whichis shownin figure2(a).

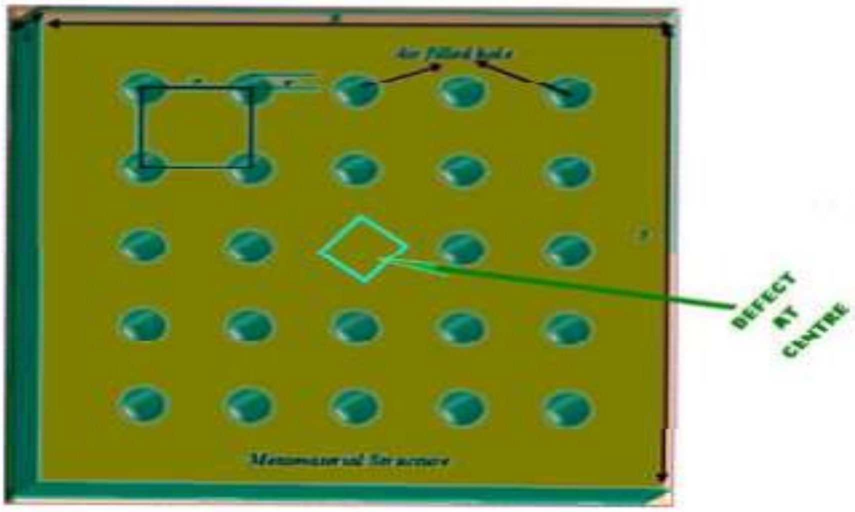

Figure2(a);schematicdiagramofproposedPCFstructure

The reasonfor choosingsuchstructure is thatdifferenttypesof laser beamscouldbe generatedwith respectto such structure.Fromabovesaid structure, it is inferred that theconfiguration ofpresentPCF playsa vitalrole togenerate differenttypesoflaser beams.Though thepresentstructure isnotnew pertaining to current research scenario, the proposed applications is novel with respect to medical surgery. Furthermovingtothe discussiononliteraturesurvey ondifferentworksusingthepresent proposedstructure,itisrealisedthatreference[3-6]dealswiththedifferentapplicationsrelatedto sensingand networking. Forexamplesmeasurementofpotassiumchlorideandi ntrallipidintheir aqueoussolution is made inreference [3]and[4]respectively.Furthera couple of paper havebeen publishedinOPTIKintheyear 2018and 2019relatedtoopticalcomputerapplications [5-6].Though the above saidresearchexploresa new kindofapplications, the currentpaper alsofocusesanoteworthy applicationsvis-à-vis themedicalapplicationswith the helpof plasmonicbased photonic structure.The principle ofoperationsdealswiththeextractionofvarious laserbeamsfromphotoniccrystalfiberwhich we want to desire fromaspecific medicaloperation. The same extractionof a signalcan be understood fromfigure2(b).

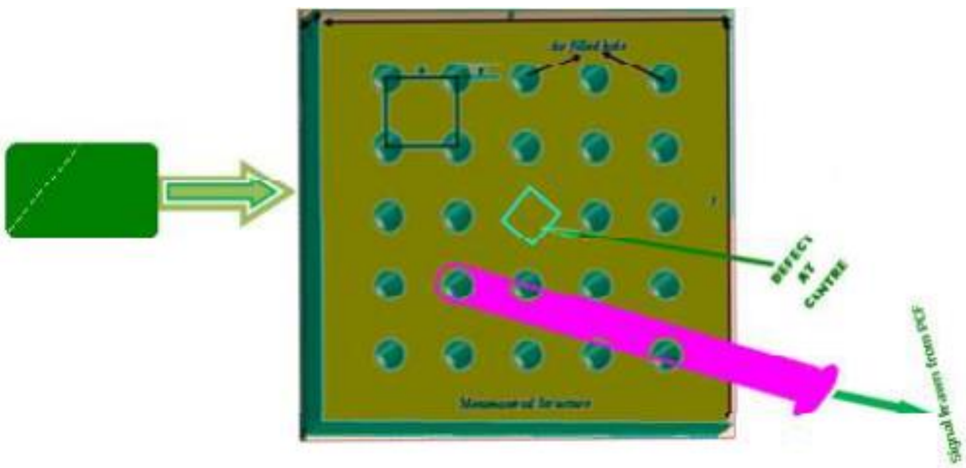

Figure2(b);thegenerationofsignalofbiomedicallaserfrom greensignal

Fromfigure2(b),asourceofgreensignalactsasinputlig htincidentstotheproposedphotoniccrystalfiberandth enthetransmittedsignalsshallbeappearedatoutputend aftersufferingvarioustypeof losses. Further itwillbeobserved that the differentsignalsemerge fromdifferentpositionsof the fiber. These differentsignalswould be given differentwavelengthsbutwe need a specific wavelength from it whichwouldbeusedformedicalsurgery purposesonly.Inthisfigure,aparticularextractingsign alis shownwithrespecttoaparticularpositionofxandy onthefibersubstratewhichisdrawnthrougha narrow fiber. Further thephysicsof principle of operation dealswith therefractiveindicesofbackgroundmaterial(plasmoni c)ofPCFwithrespecttothegreensignalandthestructur alconfigurationincludinglatticespacingofthestructur eanddiameterofairholeslaser,whichwewanttodesiref oraspecificmedicaloperation.Forexampleanalexandr itelaserhavingwavelengthof791nmisgeneratedatthe lattice spacingof 50nmanddiameter ofairholesof 17nm,whereaslattice spacingof 50nmand diameter ofair holes of45 of PCFgeneratesasignalof1045nmwavelengthoffreeele ctronlaser.Similarlyotherlasersbeamswouldbegener atedfordifferentconfiguration,whichisclearlydiscuss ed innextsection.

III. RESULTANDDISCUSSION

Asfar as the resultanddiscussionon the generationof different laser beams isconcerned, itdependson bothphysicsand mathematicsof proposedplasmonic basedphotoniccrystalfiber. The physicsof this work dealswiththestructureparameterincludingtherefracti veindicesofplasmonicmaterialincludingtheconfigur ationofthePCF including latticespacinganddiameterofair holes,wherethemathematics oftheresearchdealswiththeplanewave expansionmethod[7]throughwhichtheelectricfielddi stributioninsidethefiberismeasured.Furtherthemathe maticsinteractswiththecomputationofwavelengthoft heemergingsignalfromsaidfiber as

Fromequation(1),itisfoundthatallareknown quantitiesexcepteffectiverefractiveindicesandelectri cfieldwhichareemergingfromphotoniccrystalfiber.T heeffectiverefractiveindicescanbedeterminedbykno wingtherefractiveindexofplasmonicmaterial(backgr oundmaterial)andairfiledholesonthesubstrateatthegr eensignal.Similarlythevaluesofanelectricfieldcanbe computedwiththehelpofplanewaveexpansionmetho d,whereitdeterminestheelectricfielddistributions inthe photonic crystalfiber.Nevertheless the simulationsforgeneratingallthe wavelengthsrelated to biomedicallaserbeamshavebeenmade, resultforthesignal191nm isdisclosedhere,whichisshownin figure3.

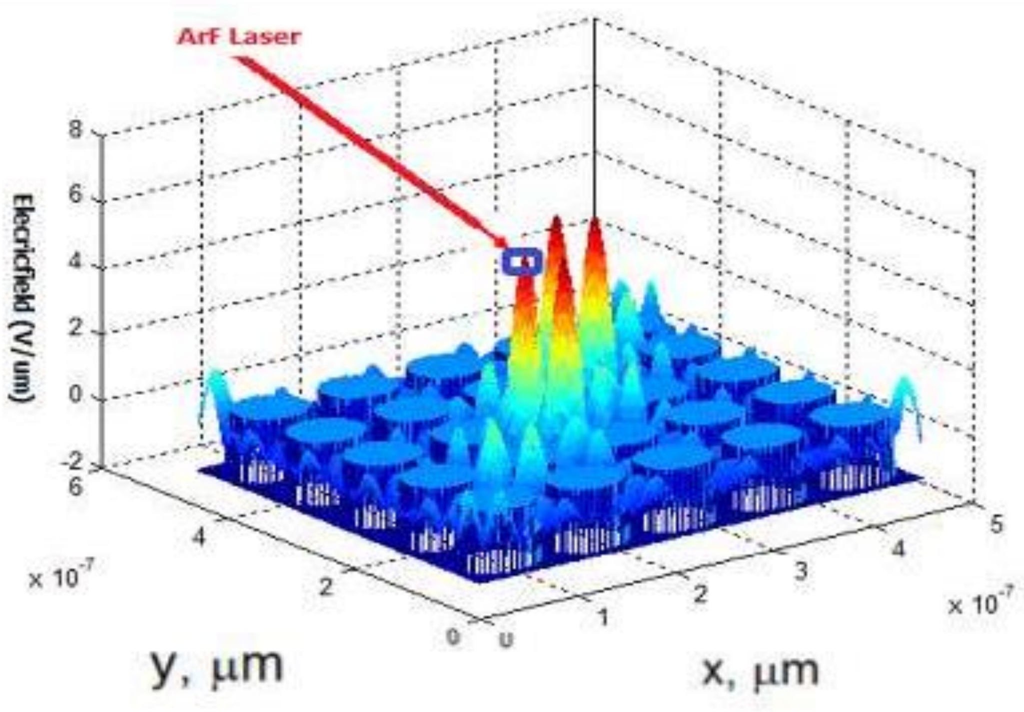

Figure 3; shows theelectric fielddistribution inplasmonic basedphotonic crystalfiber with the lattice spacinganddiameterof airholesof50nm and

39nmrespectively.Inthisfigure,the lengthandbreadth ofthefiberandfileddistributionistakenalong x,yandzaxisrespectively.Furtheritisobservedthatthe electricfileddistributionareemergedfromdifferentpositionsofthefiber.Thoughmany signalsare coming outfromthefiberbutwehavetoselectaspecificsignals whichwillbeusedfor medical operation.Moreoverobservingthelocationofxandycoordinatesofthestructureanditscorresponding toelectricfield,itisrealisedthatthevaluesofelectricfieldof1.725V/umatthecoordinate of(174nm ,195nm) (x,y) respectively. Similarly the wavelength of the emerging signal from the fiber . correspondingtotheabovesaidinformationiscomputedusingequation(1)andthecalculatedresultis 191nm, thatwavelengths iscalledasArFlasersand itisusedfor Tissueionization related tosurgical applications.

Similarly,thesimulationresultsforelectricfieldsofotherconfigurationare madeandall thewavelengthscorresponding tothesamewavelengthshavefound.Eventhoughthese graphshavenotbeendiscloseddirectly,theoutcomesof thesamehavebeendivulgedintabularformandplacedintable1

Table1,Completeinformationregardingthegenerationofsixteendifferenttypesofbio-medicallaser

Sl no	Lattice spacing innm	Diameter ofair holesin nm	Position (x,y)innm	Generating Wavelength innm	Nameofthe laserbeam	Applicationsarea
1	50	20	(174,195)	191	ArF	Tissueionization
2	50	19	(170180	223	ArCl	Skin
3	50	18	(125,128)	249	KrF	Endoscopicretina
4	50	13	(130,115)	308	ExcimerXe:Cl	Ophthalmology
5	50	14	(75,105)	351	ExcimerXe:F	Tissuedestruction
6	50	12	(125,90)	511	Cu(metal)	Ophthalmology
7	50	11	(88,60)	578	Cu(Vapour)	Ophthalmology
8	50	8	(150,60)	532	KTP	Pilmonology
9	50	46	(350,60)	1064	Nd:YAG	Endoscopic investigation
10	50	40	(55,95)	694	Ruby	Removaloftattoos
11	50	17	(140,40)	791	Alexandrite	Lithotripsy
12	50	15	(250,100)	904	GaAs	thordcicdisorders

13	50	16	(350,40)	815	Ti:Sapphire	haemoglobinand proteininvestigation
14	50	42	(320,70)	2100	Ho:YAG	Thermalkeratoplsst y
15	50	44	(220,60	2940	Er:YAG	smoothingskinand dermatology
16	50	45	(380,40)	1054	Freeelectron	ophthalmologic, otolaryngology, neurosurgical

Table1signifiesasaserialnumber,latticespacing,diameterofairholes,positionof(x,y),thewavelengthsofemerginglaserbeams,typeoflaseranditsapplicationarementionedincolumn1,2,3,4,5,6and7respectively.Moreover,theoutcomesoftable1declaresthatthepositionof(x,y)coordinatesofthefibervariesnonlinearlywiththegeneratingor emergingsignalfromthestructure.

IV. CONCLUSIONS

Thegeneration of sixteen typesofbio-medicallaser beams including gas, solid state , semiconductor and freeelectronare obtained with the helpof plasmonic basedphotoniccrystalfiber throughplanewave expansionmethod.Theprincipleofmeasurementdeals withthecomputationofelectricfieldemergingfromfiberwithrespecttothepositionofcoordinatesofthefiber. Thesimulationoutcomesdeclarethatdiameterofairholesandlatticespacing ofthestructuredeterminestheamountofwavelengthwhichemergesfromtheproposedphotoniccrystalfiber. Thepresentapproacheshelpsto medicalscience to improvethesurgicalsectionofthebiomedicalfield.

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