ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 14, Issue, 12, pp.23094-23096, December, 2022
DOI: https://doi.org/10.24941/ijcr.44355.12.2022

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

OBTAINING PHOTONIC JET BY THE RECTANGULAR WAVEGUID

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ARTICLE INFO

Article History:
Received 19th September, 2022
Received in revised form
15th October, 2022
Accepted 20th November, 2022
Published online 30th December, 2022

Key words:
Rectangular waveguide WR430,
Pyramidal Transition,
Photonic jet, Electromagnetic Beam,
Finite Element Method.

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ABSTRACT

A near-field concentration of an electromagnetic beam with a very small divergence on some propagation wavelength called "photonic jet" can be obtained by a dielectric sphere (Soon-Cheol Kong, 2010), a bi-plate guide (Takakura, 2014), a cylindrical guide (Gu, 2015), the optical fiber (Photonic jet-shaped, 2021), the conical guide (Chittaranjan Nayak, 2016) or even a cubic structure (Cheng-Yang Liu, 2015). In this paper, we present a new fully guided structure that allows to obtain the photonic jet in order to replace the device based on free space excitation with more efficiency and easier handling. The outcome of our study show that a WR430 rectangular waveguide adapted by a pyramidal transition (Air-Teflon) and specified by a rectangular cross-section extension, generates photonic jets in the near field based on the Finite Element Method (FEM).

Citation: ***Mahamout Mahamat, B., Arafat, O.B. and Sauviac, B.*. 2022.** "Obtaining photonic jet by the rectangular waveguid*". International Journal of Current Research*, 14, (12), 23094-23096.

INTRODUCTION

Recently, available studies have shown the possibility to generate a sub-wavelength focusing in the near field. This phenomenon, called photonic jet (Chen, 2004), is an interaction between light and a dielectric ball. Following this important discovery, a study (Li, 2005) proved by modeling and experimentation that this phenomenon could extend over all frequency ranges. Today, the Laboratoire Hubert Curien can develop several modeling codes allowing to modify the shape of the tip at the exit of the guide. In this order, we propose for this research a more practical alternative to free space excitation (Hyani1, 2018) and a guided structure (Hyani1, 2010) in the form of a Teflon-loaded horn antenna terminated by a cylindrical tip, which requires re-dimensioning each time the horn is changed. The new fully guided structure excites the higher order m (TE01) at 5GHz which is characterized by a simplified geometry. In addition to its computational time compared to the simulation, this new profile allows to obtain photonic jets remarkable by their concentration.

GUIDING STUDY STRUCTURE: The studied structure is a rectangular guide WR430 made of a dielectric material (Air or Teflon) surrounded by a conductor of rectangular shape of dimensions a= 54.61mm, b=109.22mm and the z direction is assumed unlimited.

We approach our problem through the numerical method based on the Finite Element Method (FEM). This method allows to solve electromagnetic problems based on Maxwell's equations taking into account the boundary conditions specific to the studied configuration. The FEM is part of the numerical methods of type "discretization of the study domain". To have an approximate solution, we base ourselves on the boundary conditions and excitations. We have applied this method for our study because of its efficiency. For a frequency of 5 GHz, we plot the dispersion in Figure 1 for the case of vacuum and Teflon. We observe ten (10) modes in the case of air and twenty-one (21) modes for Teflon but we are interested in the first three (TE10, TE20 and TE01) which have cut-off frequencies of 1.39GHz and 2.738GHz respectively in vacuum and 0.916GHz and 1.872GHz in Teflon with the mode TE20 and TE01 superimposed.

TRANSITION IN THE WR430 RECTANGULAR WAVEGUIDE

We come the different modes in the guide WR430, we want to adapt this guide by changing the index medium from air to Teflon which requires a transition to make a change of medium in a progressive way. We introduce a teflon pyramid in the part of the guide filled with air as we can see in Figure 3. By optimizing the length of the pyramid, we plot the transmission and reflection parameters of this adaptation in Figure 4.

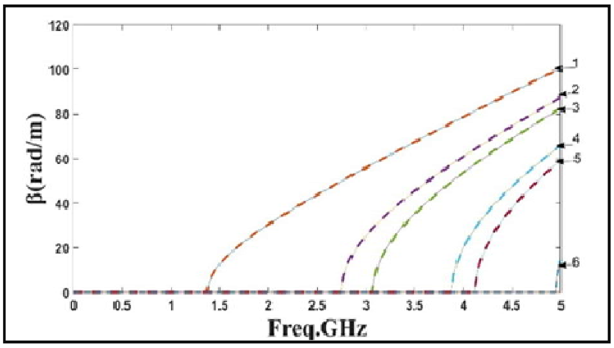

Fig. 1.Mode dispersion diagram in the WR-430 rectangular waveguide from simulation and calculation consisting of Air at 5GHz

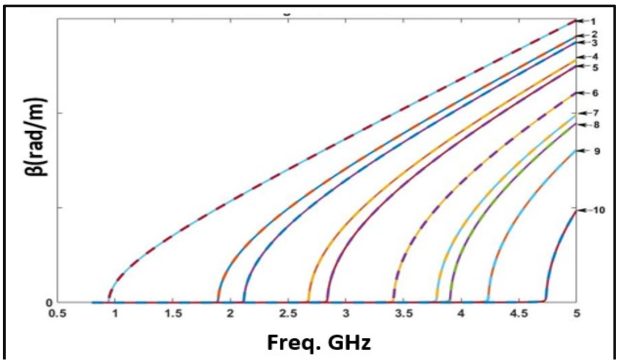

Fig. 2.Mode dispersion diagram in the WR-430 rectangular waveguide from simulation and calculation consisting of Teflon at 5GHz

The three figures of this adaptation that the wave propagates almost without losses with a reflection is less than -40dB for each case. This result allows us to say that introducing the Teflon pyramid between the two media (Teflon air) allows to make a change in a progressive way and have a good adaptation.

OBTAINING PHOTONIC JET AT THE EXIT OF THE WAVEGUIDE: We add to this adapted structure a rectangular Teflon end cap characterized by its width (Lx), height (Ly) and depth (Lz) (Figure 5).

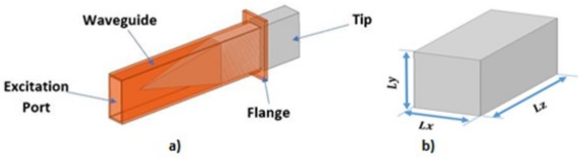

Fig. 5.Three-dimensional view: (a) rectangular waveguide with pyramidal transition terminated by a rectangular cross-section end cap and (b) rectangular cross-section end cap

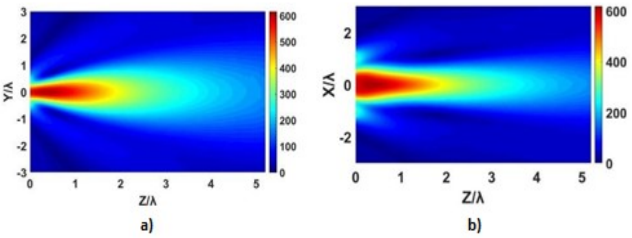

Fig. 6. The normalized transverse electric field intensity in the plane defined by the propagation direction z and the vertical polarization of the y (a) and x (b) excitation in TE01 mode at 5GHz

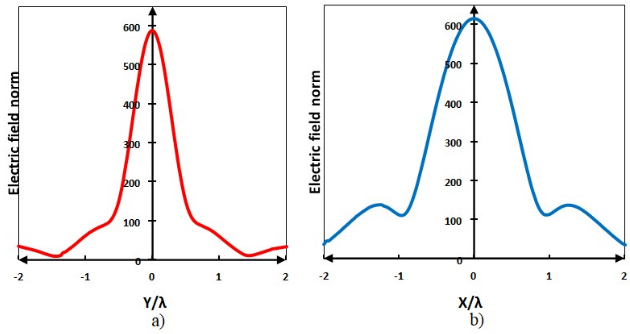

Fig. 7. Cross-section of the normalized vertical field intensity defined by polarization of the excitation: a) y and b) x

The width at half height (FWHM), the focal point (Zmax), the beam length and the maximum intensity (Emax) as a function of the tip dimensions (Lx, Ly and Lz). As illustrated in Figure 6, the electric field intensity is maximized by the dimensions of the rectangular section extension given by: width Lx=69mm, height Ly=138mm and depth Lz=120mm). We have the maximum intensity of 600V/m with focal point of 1/3λ. We plot the cross section of the electric field norm in Figure 7. The cross-section of the vertical field normalization intensity on the x and y axis, we have the width at half-width on the x axis (FWHMx) of 1.21λ and on the y axis (FWHMy) of 0.57λ.

CONCLUSION

We have demonstrated that the rectangular WR430 can generate the photon beam at a frequency of 5GHz with a high concentration for the working space more than three times the wavelength. This result is encouraging with three advantages: the choice of the standard guide which does not need to be manufactured, a gain in calculation time with the simpler shape of the tip and a good concentration of the electric field intensity at the exit of this rectangular section tip. This could be used to make a detection with more sensitivity. The next work will be to make a parametric study of the tip in order to improve the photonic jet with a more sensitive focusing to allow to make the measurements more efficiently.

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