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A NEW TRAVELING-WAVE MIXED-MODE RF WINDOW

WITH A LOW ELECTRIC FIELD IN CERAMIC-METAL BRAZING AREA

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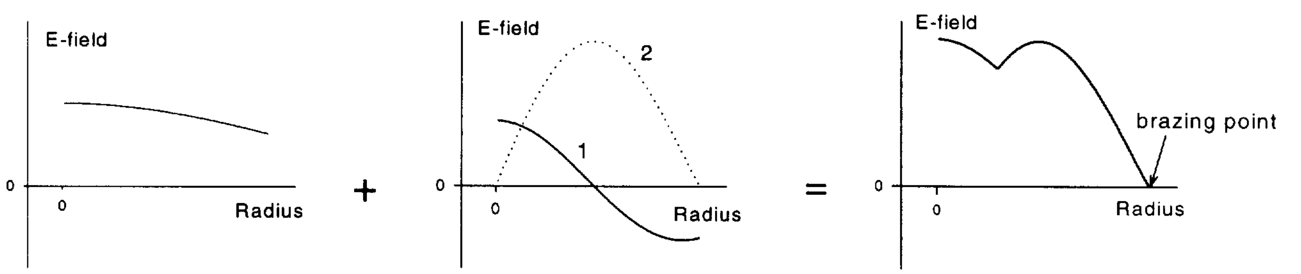
Abstract

The new approach to the RF window design with a low electric field value at the dielectric, and especially in dielectric-metal brazing area, is proposed. Two samples of X-band windows based on this approach are presented.

Introduction

An output window an important factor that determines reliability and lifetime of powerful vacuum microwave sources. In future linear colliders several thousands of klystrons with the output power approaching 100 MW will be used. Hence, it is vital to maximize lifetime of such klystron in order to reduce maintenance charges in such large-scale installation. The main reason for the destruction of the windows of superpowerful devices is a high frequency breakdown at the dielectric due to the high electric field there. As was shown in [1], the best material for powerful RF windows is Al_2O_3 ceramics. The electric field strength of 8-kV/mm [1] is considered to be the limit for the ceramics, even if manufactured from a purest possible material using available modern technologies. An effective remedy for a high strength is a usage of pure traveling wave (TW) in dielectric [2]. This allows a considerably increase in the power limit in the window. The "weakest" point in the windows is the ceramics-to-metal seal. The field strength in this area can be either reduced with the special screens [3], or completely avoided by using the TE_{01} wave is [4]. However, the first approach is technologically complicated since



TE_{11}-mode electric field vs radius on the dielectric-vacuum surface

TM_{11}-mode electric field vs radius on the dielectric-vacuum surface.
1 - tangential field
2 - normal field

Sum of electric fields of TE_{11} and TM_{11} modes.The field at the periphery (brazin point) is zero.

Fig 1.

The principles to obtain a zero electric field at brazing points by combining different modes.
To reduce the maximum electric field, the modes propagation regime should be close to traveling waves in the dielectric.

a rather sophisticated geometry has to be formed close to the ceramics. To realize the second approach, complex and expensive TE_{10}-TE_{01} wave converters are necessary. This paper presents constructions of X-band windows that are technologically simple but lead to low field strengths at the ceramics and approximately zero strength at the seal.

Basic idea

All the windows with TW in the dielectric use only one mode, to the author's knowledge [2,4]. Namely, RF energy is carried by only one mode – either TE_{11}, or TE_{01}. The idea exploited in the development of new windows is to arrange the combination of space harmonics on the dielectric surface so that electric field strength value almost vanishes at the brazing area. At the same time, the mode propagation regime in the dielectric is maintained to be close to that of pure traveling waves. The principles of eliminating E-field at the brazing points are illustrated in Fig.1. For the sake of comparison, the maximum electric field strength on the ceramics vs. the radius are presented in Fig.2 for three window cases: the traditional TE_{11} one-mode self-consistent half-wavelength window, the window with TW in the dielectric, and the new TE_{11}+TM_{11} mixed-mode window. The principles of operation of

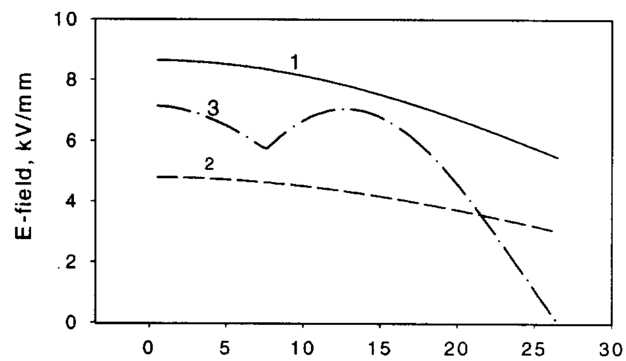


Fig 2.

Maximum electric field strength on the dielectric surface vs radius for different types of windows.
Dielectric diameter - 53mm
Dielectric permittivity - 9.8
Frequency - 11.4 GHz
Transmitted power - 100 MW

1 - TE_{11} half-wavelength window
2 - TE_{11} traveling wave window
3 - TE_{11}+TM_{11} traveling wave window

new windows are easy to understand from Fig.3. The modes in the required combination are launched in the semi-infinite waveguide filled with dielectric. The matching elements in the vacuum part are chosen so as to guarantee the absence of reflected waves in the dielectric. Then the geometry is reflected with respect to the R-R plane. Since the phase velocities of lower modes in the dielectric with a large permittivity are close, the condition of a low electric field strength is valid for the whole 1/4-wavelength dielectric, which is optimal for the bandwidth.

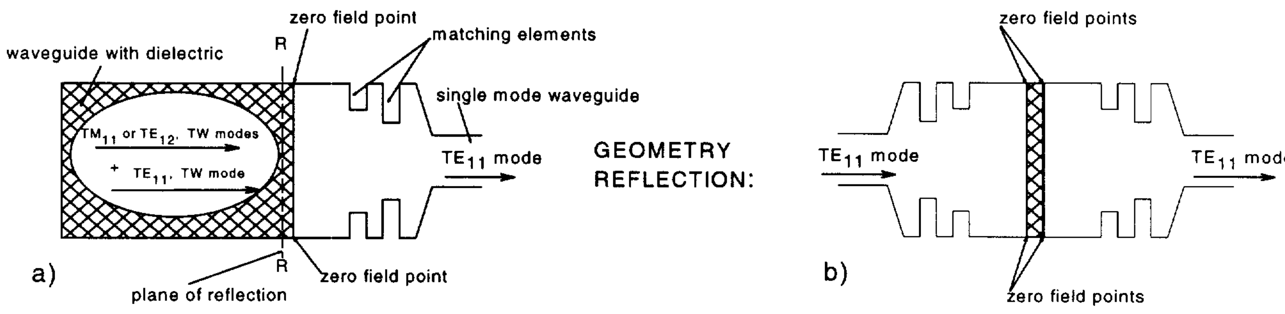


Fig 3.

Principles of TW multimode window having a zero field at brazing points.

a) The modes in the required combination are launched in the semi-infinite waveguide filled with the dielectric. The matching elements in the vacuum part are chosen so as to eliminate any reflected waves in the dielectric.

b) The window is obtained via reflection the geometry with respect to R-R plane.

The windows developed

Based on this idea, the windows for 11424 MHz have been developed with the dielectric 53 and 64 mm in diameter. The permittivity was assumed to be equal to 9.8, i.e. that of Al_2O_3 ceramics. The dielectric thickness was chosen to be close to 1/4-wavelength to ensure the maximum bandwidth and the maximum tuning away of the operating frequency from the "ghost" modes. With the diameter 53 mm, this made 2 mm, whereas for 64 mm it was 2.15 mm. All the computations were done using HFSS 4.0 code. The shapes of the windows and their main characteristics are presented in Figs. 4 and 5. The field strengths are normalized for the average power 100 MW transmitted through the window.

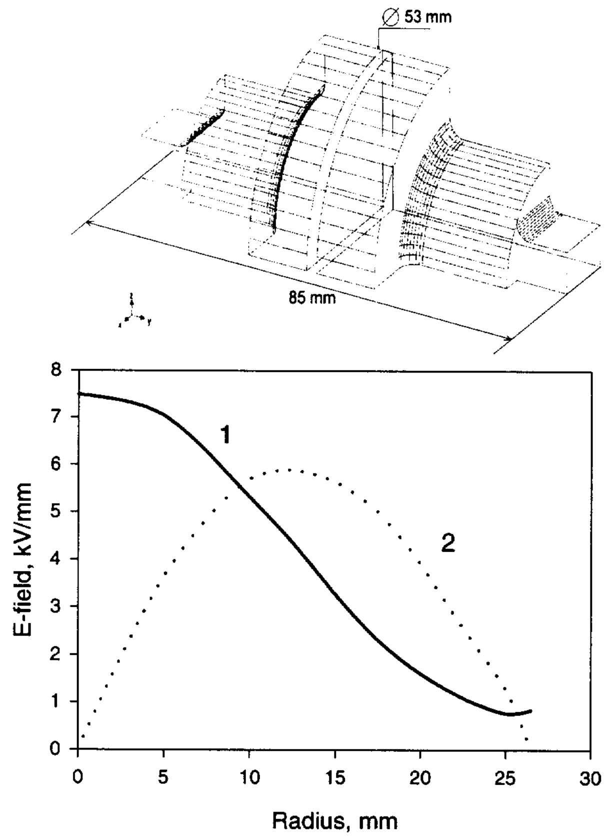


Fig. 4

Shape of the window 53 mm in diameter, and E-field on the dielectric surface at 100 MW.

1 - tangential field
2- normal field

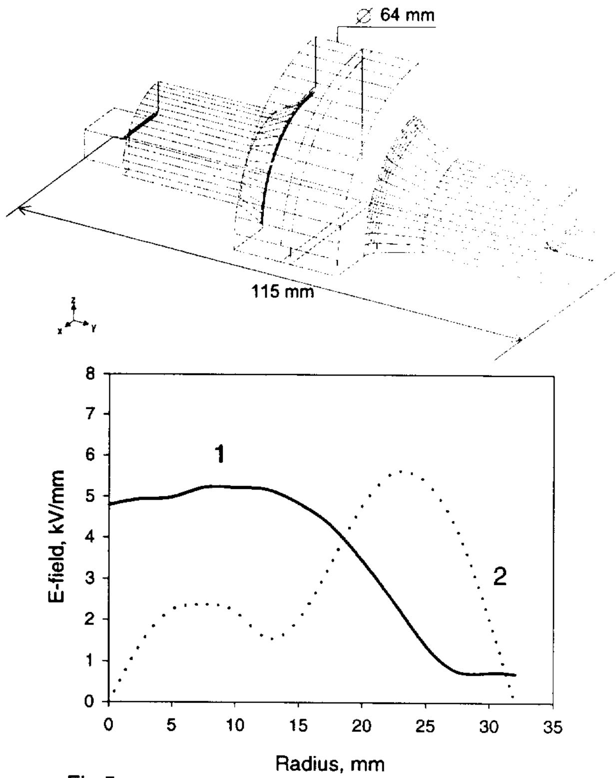


Fig.5

Shape of the window 64 mm in diameter, and E-fields on the dielectric surface at 100 MW.

1 - tangential field
2 - normal field

Conclusion

As is clear from the figures, the new windows are characterized by small strengths of E-fields at the dielectric periphery, which is favorable for the metal-to-ceramics brazing. The maximum field strength at the dielectric is small enough that a reliable operation of the windows is expected at the pulse power above tens of megawatts. The calculated bandwidth at –20 dB is more than 300 MHz. The simple shape of the windows also allows easy manufacturing and cost saving.

Acknowledgments

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