

Fig. 4 shows the life-test results of seven fibre coupled devices. Laser diodes with 100 μ m wide emitting apertures were used for the test. They were fibre coupled into 100 μ m diameter fibres. Devices have been pre-screened in the standard production procedure. The power shown in the Figure is the CW output power out of 100 μ m diameter fibre. The life-test was carried out in the constant current mode with a heat-sink temperature of 30°C. As reported before, no sudden failure was observed for InGaAs/AlGaAs diode lasers. There was no detectable degradation for five devices after > 2200h. Two other devices had degradation rates of 0.8% and 0.4% per thousand hours, respectively. In the last 1300h, there was no measurable degradation for all seven devices. The average over all degradation rates for all seven devices is 0.17% per thousand hours. The average degradation rate is linearly extrapolated to a lifetime (20% power degradation) better than 1.2×10^5 h at 30°C. This lifetime is comparable to the best reported lifetime of 100 μ m wide emitting aperture multimode AlGaAs/GaAs diode lasers [7].

In conclusion, we demonstrated 6W CW output power from the uncoated 100 μ m wide facets of an AlGaAs/InGaAs (915nm) broad area laser diode. Internal losses as low as 72cm⁻¹ were observed for the laser diodes. No significant thermal rolling was observed for up to 2W CW operation at 80°C. The reliability of the laser diodes was evidenced in the accumulated 2300h life-test of the fibre coupled devices. No degradation was observed for five out of seven tested devices at the CW output power of > 1W from 100 μ m diameter fibre.

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Full-wave analysis of image hybrid dielectric/HTS resonator

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Indexing terms: Dielectric resonators, Superconducting resonators

An analysis of the image hybrid dielectric/HTS resonator is carried out. A full-wave radial mode-matching method is used to obtain the electromagnetic fields inside the resonator for single TE₀₁ and dual HE₁₁ modes. The resonator power-handling capability is estimated from the field at the surface of the HTS film, assuming a certain value for the critical field of the HTS film.

Introduction: The high power performance of high-temperature superconductor (HTS) communication filters is limited by the critical current of HTS films. High current densities due to edge effects in planar transmission-line-based filters, prevent their use for high-power applications. Recently, there has been some interest in the new hybrid dielectric/HTS resonator as a possible resonator structure for high-power HTS filters [1, 2]. This resonator structure provides small size, a high quality factor and good thermal stability, allowing the realisation of reduced size hybrid dielectric/HTS dual-mode filters for high-power applications.

The optimal performance of these filters requires proper design of the resonators included in them. As a previous step to the design, this work presents the numerical analysis of the hybrid/HTS resonator. A full-wave radial mode-matching method is used which, for the geometry considered, provides low computational cost with high accuracy. From this analysis, features that are essential to filter performance, such as resonant frequencies, quality factors and power-handling capability, are calculated. The results are compared with measured data.

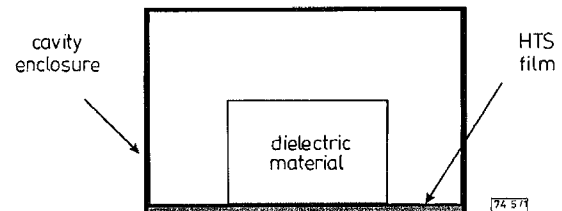


Fig. 1 Hybrid dielectric/HTS resonator

Whole structure has cylindrical symmetry

Hybrid dielectric/high temperature superconductor resonator: The resonator structure (Fig. 1) consists of a dielectric resonator on top of an HTS thin film [1]. The HTS film behaves as a perfect electric conductor and does not modify the fields of TE₀₁/HE₁₁ modes since they do not have a tangential electric field on the surface. As argued in [2], the resonator is equivalent to the symmetric HEE₁₁ double size resonator in suspended configuration.

There is no interest in realising the structure in Fig. 1 with a normal bottom plane: metal losses are high and severely compromise the overall performance of the resonator. Moreover, this resonator has several advantages over a conventional room temperature suspended resonator: size reduction by one half, low losses of dielectric material at cryogenic temperatures and very good thermal stability. The idea has been successfully implemented to develop a dual mode image hybrid dielectric/HTS filter [2].

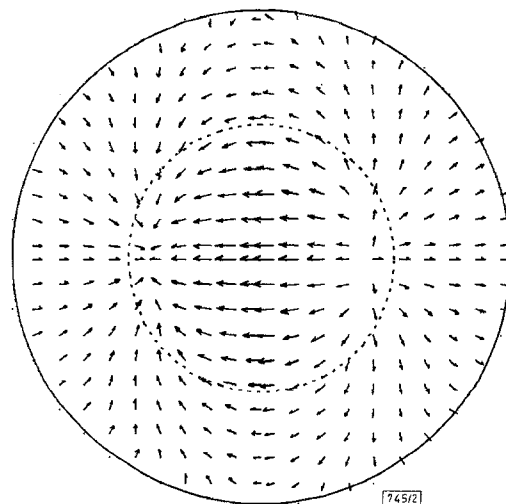


Fig. 2 HE₁₁ mode current distribution on HTS thin film

Radial currents at edge of HTS film are important

Field and current distribution: The method of analysis computes the field distribution of any resonant mode by using a method similar to the one used in [3]. The field intensity is much higher inside the dielectric material. Thus, if resonator design is appropriate, the overall loss of the device is dominated by dielectric losses.

Once the fields in the cavity are known, the current distribution on the surface of the HTS film is computed from the tangential magnetic field.

The current of the TE₀₁ mode is circumferential and therefore there is no current flowing from the edge of the HTS film to the enclosure. On the contrary, the HE₁₁ mode has radial currents (Fig. 2), and a good contact is needed between the HTS film and the enclosure.

Resonant frequency and unloaded quality factor: Resonant frequencies were obtained considering no loss in the cavity enclosure, dielectric material and HTS film. Losses were taken into account later through a perturbational analysis that led to the quality factors. Measurements of the resonator have been performed at 300 and 77K. Measurements at 77K were done in liquid nitrogen and using silver or HTS film for the cavity bottom plate. At 300K we used only silver in the bottom plate of the cavity.

The dielectric used is ZrSnTiO₄ with a quality factor of 16×10^3 at 300K. This material doubles its quality factor when cooled to 77K [4]. The main loss contribution is due to the dielectric material itself and it highly compromises the overall quality factor of the resonator. The second major loss contribution is the silver plated enclosure. Other loss contributions can be neglected.

Good agreement is found between the theoretical and measured values for the TE₀₁ singlemode (Table 1). For the HE₁₁ dual mode however, the measurements were not reliable due to the existence of significant radial currents at the edge of the film (Fig. 2). In our measurements, this contact was not ensured, and therefore, measured quality factors were found to be lower than the expected theoretical values.

Table 1: Theoretical and measured values for TE₀₁ singlemode

Mode and temperature	Measured		Computed	
	f	Q	f	Q
TE ₀₁ mode at 300K	GHz		GHz	
	2.166	9600	2.174	8704
TE ₀₁ mode at 77K w/o HTS film	2.148	20300	2.174	18231
TE ₀₁ mode at 77K with HTS film	2.146	31500	2.174	28838

Dielectric constant 36.3; resonator dimensions 1.125" \times 0.506"; cavity dimensions 2.10" \times 1.034"

Power-handling capability: The high nonlinearity of HTS films is a matter of concern in the image hybrid dielectric/HTS resonator [5]. There is a critical current above which the quality factor of an HTS film rapidly decays to an extremely low value. This current is associated with a critical magnetic field applied to the surface of the film. For a given input power, the energy stored in the resonator can be calculated from a closed expression [6]. When the resonator is critically coupled, the following equation can be used:

$$W = (Q/\omega)P_{in} \quad (1)$$

where Q is the quality factor of the resonator, ω is the resonant frequency, W is the energy stored in the resonator and P_{in} is the input power. This scaling is done by noting that the maximum peak value of the magnetic field on the HTS surface is proportional to the energy stored in the resonator, with a proportionality constant which only depends on the mode considered. Thus, for a given mode:

$$\frac{H_{max}}{\sqrt{W}} = \frac{H_{max}^*}{\sqrt{W^*}} \quad (2)$$

where H_{max} is the actual maximum peak value of magnetic field, H_{max}^* is the value obtained through numerical calculation and W^* is the energy obtained in the numerical analysis. By combining eqns. 1 and 2, the maximum magnetic field H_{max} is calculated for several values of input power (Table 2).

Table 2: Maximum microwave magnetic field on surface of HTS film for different input power values

P_{in} [W]	20	40	60	80
H_{max} TE ₀₁ [A/m]	2.83×10^3	4.01×10^3	4.91×10^3	5.67×10^3
H_{max} HE ₁₁ [A/m]	7.58×10^3	1.07×10^4	1.31×10^4	1.51×10^4

The results indicate that the TE₀₁ mode can sustain higher power levels than the HE₁₁ mode. A value for the critical magnetic field which induces the critical current in the HTS film is found to be $\sim 1.5 \times 10^4$ A/m in [7]. Assuming this critical field value, the dual-mode HE₁₁ resonator starts to fail for an input power of 80 W, whereas the singlemode TE₀₁ resonator can handle a power of 560W. This is in reasonable agreement with other preliminary measurements.

Conclusions: The hybrid dielectric/HTS resonator has been analysed using a full-wave radial mode-matching technique. Agreement has been found between measured and simulated results. The method discussed can be used to compute the field or current distributions and, from them, the resonant frequency and quality factor of the resonator. The current distribution on the HTS film for single TE₀₁ and dual HE₁₁ modes has been computed. The existence of radial currents in the HE₁₁ mode, requires a good contact between the housing and the film.

The performance of the dielectric/HTS resonator at 77 K is limited by dielectric material loss. Therefore, optimised materials at cryogenic temperatures, with low loss and a high dielectric constant, are needed in order to build competitive resonators and filters.

Finally, the power handling capability of the resonator has been determined by relating the energy in the resonator with the input power and the maximum peak value of the magnetic field at the surface of the HTS film. Therefore, if some value of critical field is assumed for the HTS film, the power handling capability of the resonator can be estimated.

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