3-FOLD & 5-FOLD HELICALLY CORRUGATED WAVEGUIDE MICROWAVE PULSE COMPRESSOR

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Abstract

The results of 3-fold helically corrugated waveguide microwave pulse compression experiments are presented; a 80 ns pulse having peak power of 5.5 kW was compressed into a 140 kW peak power pulse of 1.5 ns duration. To enhance the power capabilities of the microwave pulse compressor a larger diameter 5-fold helical waveguide structure was studied; the eigenwave dispersion of the 5-fold helix obtained using numerical, analytical, and experimental techniques is discussed.

I. INTRODUCTION

X-band microwave pulse compression has applications in radar technology and plasma diagnostics [1]. A 3-fold helical corrugation [2] was studied which couples a pair of partial modes of the smoothbore circular waveguide having significantly different group velocities: $TE_{2,1}$ close to cut-off and the $TE_{1,1}$ mode far from cut-off. At non-zero amplitude of corrugation, resonant coupling between the modes occurs when their axial and azimuthal wave numbers satisfy the Bragg conditions resulting in the operating eigenmode [2,3]. As a result, in the frequency region of their resonant coupling, the resultant eigenmode has a strong frequency dependent group velocity which is favourable for pulse compression [2,4,5].

3-FOLD MICROWAVE PULSE COMPRESSION EXPERIMENTS

A modulated, frequency-swept microwave pulse was created using an arbitrary waveform generator and vector signal generator (Figure 1). The pulse was then amplified using a high-power 7kW TWT (TMD PTC6321), with the pulse amplitude and duration measured prior to entry of the compressor. The frequency sweep was optimised to be 9.61 – 9.10 GHz, (Figure 2). The maximum available (for this compressor) power compression ratio of 25 was achieved, with a 5.6kW (average over the pulse), 80-ns duration microwave pulse, compressed to a 140kW, 1.5-ns duration pulse (Figure 3).

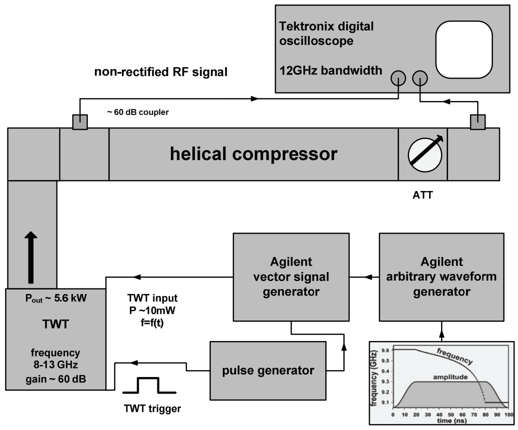

Figure 1. Experimental set-up

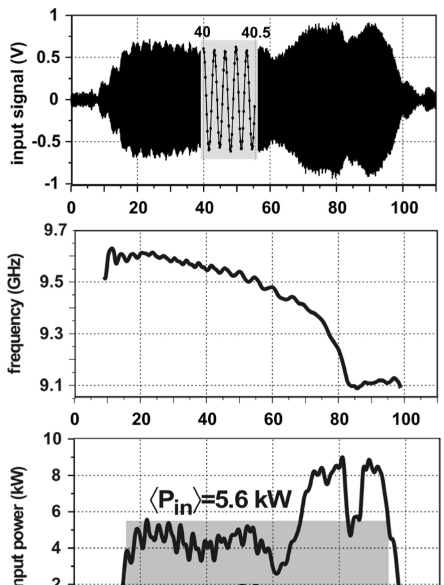

Figure 2. Input pulse details for pulse compression experiment.

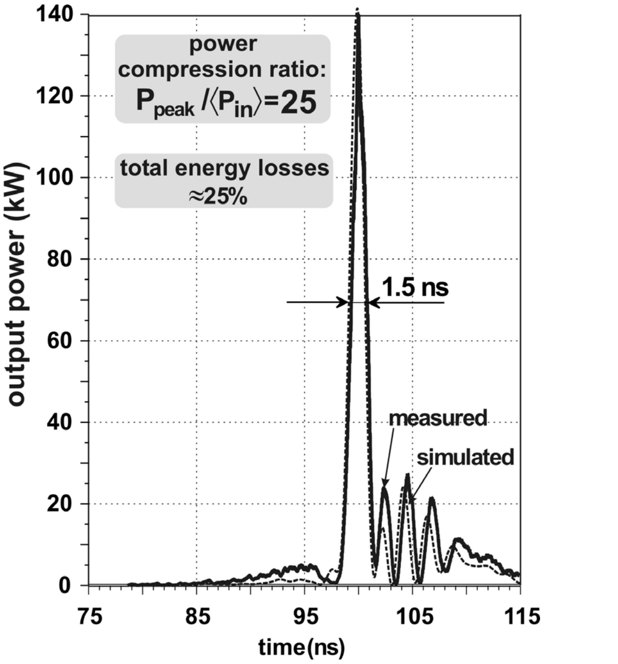

Figure 3. Measured (solid line) and simulated (dashed line) compressed pulse.

II. 5-FOLD HELICAL WAVEGUIDE COMPRESSOR

For enhanced power capabilities an overmoded large diameter 5-fold copper helical waveguide structure system was designed to compress microwave pulses with frequency modulation within the interval of 9.61-9.10 GHz and simultaneously provide low reflection of input radiation within a frequency interval of 8-10 GHz. The set-up (Figure 4) consists of an input cone to introduce the radiation from the input source, a mode converter to convert the input mode into the operating mode of the compressor, an intermediate cone to transport the radiation keeping acceptable mode purity and a pulse compressor to compress the frequency modulated radiation. At the input cone the radiation will be in the form of a left-handed circularly polarized $TE_{1,1}$ mode. The output radiation from the mode converter will be in the form of a right-handed circularly polarized $TE_{3,1}$ mode which enters the compressor to couple with the close-to-cutoff $TE_{2,2}$ mode. The reciprocal set-up is required on the output side of the pulse compressor to obtain the compressed $TE_{1,1}$ wave. The 5-fold compressor is capable of handling GW levels of power [6].

The dispersion characteristics of the eigenwave were studied using 3 different techniques; numerical (CST microwave studio-MWS), analytical (coupled wave theory), and experimental (vector network analyzer). Firstly, a single period of the 5-fold helix was modeled in MWS. Using the dedicated eigenmode solver within MWS the eigenmode was simulated (Figure 5) for various boundary phase angles (ϕ). The corresponding axial wavenumber k_z was calculated from, $k_z = \phi/d$ where d is the corrugation period. Secondly, using coupled wave theory [7] the eigenwave dispersion was calculated in Matlab for the interaction of the two electromagnetic waves (the $TE_{3,1}$ and $TE_{2,2}$) present in the 5-fold helix

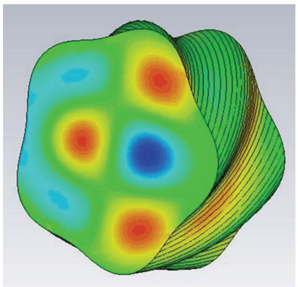

Figure 5. Eigenmode profile of transverse electric field

Thirdly, a vector network analyzer (VNA) was used to measure the phase of the eigenwave in a 6 period section of the 5-fold compressor (Figure 6).

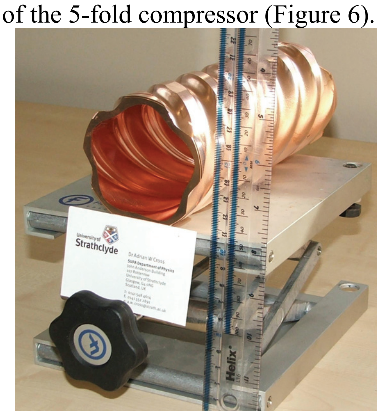

Figure 6. A section (6-periods) of 5-fold waveguide.

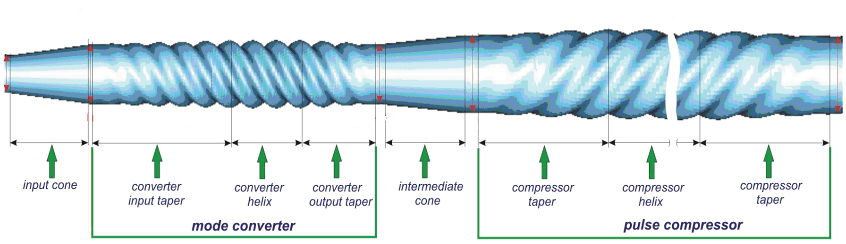

Figure 4. 5-fold microwave compressor set-up

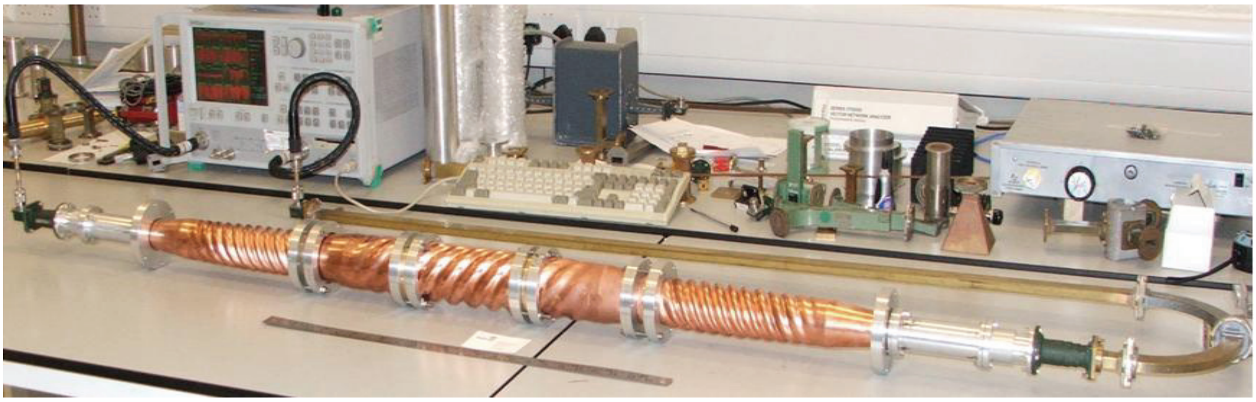

Figure 7. Photograph of the 5-fold compressor and VNA measurement system

The VNA was calibrated using a line-reflect-line method, (Figure 7). The scattering parameter S_{21} was recorded as a function of frequency. A measurement was taken when the section of 5-fold helix was present and similar measurement was taken without the helix present. The difference in the two measurements was analyzed digitally using Microsoft Excel. The results from the three (MWS, coupled wave theory, VNA) techniques are shown in Figure 8.

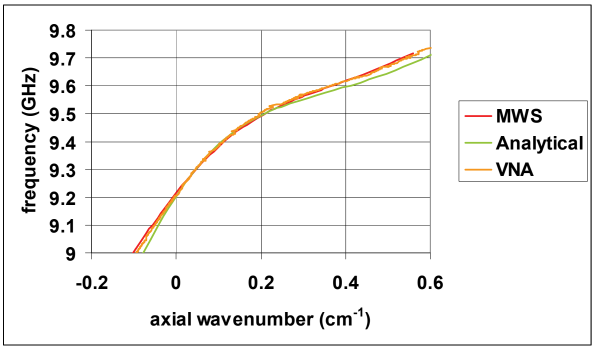

Figure 8. Eigenwave dispersion results

III. SUMMARY

Future work will involve carrying out experiments with the full length (approx. 3m) of the 5-fold pulse compressor to perform sweep-frequency based microwave pulse compression experiments at low powers (mW) and medium powers (kW).

IV. ACKNOWLEDGEMENTS

The authors thank the UK EPSRC, Dstl, TMD and the Faraday Partnership in High-Power RF, the Russian Foundation for Basic Research (grant 07-08-00244) and the Presidium of the Russian Academy of Sciences for supporting this work.

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