MULTI-MODE SLED-II PULSE COMPRESSORS


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Outline

1. Pulse compressors based on a set of cylindrical multi-mode cavities:
   • Kazakov’s idea.
   • Low power tests of 4-cell pulse compressor.
   • Development of the primary idea.
2. One-channel SLED-II pulse compressor.
3. Compressors based on multi-mirror delay lines.
In order to reduce the total length of delay lines, S. Kazakov suggested the idea to use a set of TE\textsubscript{01} cavities which are to be an equivalent of the delay line.
The necessary condition for the Kazakov’s solution is to avoid spurious high-Q resonances in the frequency band which at least wider than spectrum width of the output compressor’s pulse:

$|f-f_0| >> \Delta f$  \hspace{1cm} (1)

where $f$ – is a real frequency of the nearest eigen mode, $f_0$ – is an operating frequency, and $\Delta f$ – is a width of spectrum of the output pulse.

The low-Q resonances are not dangerous while Q-factors are much less than:

$Q^* = \frac{f_0}{\Delta f}$  \hspace{1cm} (2)

The conditions (1-2) are satisfied, in particular, if the cavity has spectrum of eigen modes consisted of the quasi-degenerated modes only.
Delay cavity of Kazakov’s type chosen for low-power tests

The delaying time at 11.4 GHz equals 23 ns/m.

Phase of the reflected wave for the 4-cell chain.
4-cavity 34.27 GHz prototype of pulse compressor

Phase of reflection from the compressor. Here the resonant frequency is 34.253 GHz.

Experimental setup
Simulation of the compression ($\tau_{in}=200$ ns, $s=5$)

Simulation of the output pulse for the tested 4-cell compressor (no phase reverse).

Simulation of the output pulse for the designed 4-cell compressor (with $\pi$ phase reverse).
Experimental plot of the pulse (yellow) formed by the compressor (no phase reverse).

Experimental plot of the pulse (yellow) formed by the compressor (with phase reverse).
Development of the primary idea (f=34 GHz)

<table>
<thead>
<tr>
<th>№</th>
<th>L1 (mm)</th>
<th>L2 (mm)</th>
<th>D1 (mm)</th>
<th>D2 (mm)</th>
<th>Delay time (ns/m)</th>
<th>Ohmic Loss/delay time (%/ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Kazakov”</td>
<td>14.7</td>
<td>129.07</td>
<td>18</td>
<td>89.2</td>
<td>22.9</td>
<td>0.045</td>
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<tr>
<td>“Long”</td>
<td>5</td>
<td>100.27</td>
<td>13.98</td>
<td>69.3</td>
<td>52.8</td>
<td>0.059</td>
</tr>
<tr>
<td>“Short”</td>
<td>5</td>
<td>25.14</td>
<td>11.28</td>
<td>171.35</td>
<td>152.3</td>
<td>0.073</td>
</tr>
</tbody>
</table>

“Short” cavity allows to increase essentially the delay time per meter of structure.

Sizes of the cavity
The 11.35 GHz cavity with the curved end faces

There are cavities those eigen modes are strictly degenerated. Most known example from optics is a so-called confocal two-mirror cavity.

Reflection and transmission coefficients
Idea of one-channel SLED pulse compressor based on ring-like cavity

The ring-like cavity allows compression using single channel instead of double channels. The necessary condition is that the eigen mode B of storage cavity is coupled with the forward mode A only.
• The operating mode of the axis-symmetrical cavity consists of TE$_{01}$ mode and TE$_{02}$ mode which propagate toward each other. These modes are transformed each to other in the both ends of the delay line by means of special reflecting converters. The feeding wave is the TE$_{11}$ mode which goes through the mentioned converters without conversion into any other mode.
• The transmitting TE$_{11}$ mode is coupled selectively with the forward TE$_{01}$ mode only by means of the serpent-like periodic mode converter included in the delay line. This converter should provide optimal mutual conversion TE$_{11}$-TE$_{01}$ in order to obtain high compression efficiency. The backward TE$_{02}$ mode should be not perturbed by the coupling converter.
The reflector does not perturb TE\textsubscript{11} mode propagated through the compressor.

The field structure at the reflector under TE\textsubscript{01} incidence.

Calculation of modes at the TE\textsubscript{01}-TE\textsubscript{02} mode reflector
The field structure at the mode coupler under $\text{TE}_{11}$ incidence.

The desired coupling coefficient is 0.5 on power for $s=4$. 
The modes A, B, and C could be arbitrary. For example, scheme with axisymmetrical modes (A=TE_{01}, B=TE_{02}, C=TE_{03}) seems attractive.
Compressors based on multi-mirror delay lines

More compact modification of the previous pulse compressor

SLED-II pulse compressor based on multi-mirror delaying lines
Most compact delay lines are shaped by mirror systems where the traveling wave many times crosses itself. The example of such systems is a star-type mirror line. Under the delay time 25 ns the star diameter is 750 mm, the sizes of confocal mirrors are $187 \times 180$ mm$^2$. 
Conclusion

• The SLED-II pulse compressor, based on $\text{TE}_{0n}$ mode cavity chains, is the prospect idea. This allows to reduce 10 - 50 times the length of delaying lines. The main criteria for designing of such cavities are that the design should allow an existence of the quasi-degenerated modes only amongst high-Q eigen modes. The carried out simulations and low power tests at 34.27 GHz confirm good efficiency.

• The one-channel $\text{TE}_{01}-\text{TE}_{02}$ SLED-II pulse compressor is suggested. It does not require 3 dB coupler. Possibilities to reduce the length require additional investigations.

• SLED-II pulse compressors, based on multi-mirror delaying lines, are suggested for frequencies 30 -100 GHz. They allow to provide high efficiency and excellent compactness. The main advantage is the flat output pulse shape.