Abstract
Compact SLED-II pulse compressors are considered. The primary idea to use a set of the cylindrical multi-mode cavities, to be free of high-Q resonances around the 11.4 GHz, is analyzed [2]. This idea is developed, in order to provide more delaying time per miter of the line. Another idea to provide compactness is to avoid two-channel scheme with 3dB coupler usually used for SLED-II pulse compressors. A reflectionless delay line is built in this case, using coupling in a form of the non-symmetrical mode converter. SLED-II pulse compressors of higher frequency bands also are considered. It is suggested to shape these compressors on a base of the multi-mirror transmission lines. The operating mode in this case is a Gaussian wavebeam traveling between mirrors.

PULSE COMPRESSORS BASED ON A SET OF CYLINDRICAL MULTI-MODE CAVITIES
The SLED-II pulse compressor consists of two delaying lines, operated with TE01 modes, which are coupled by means of 3 dB coupler [1].

\begin{align}
  |f - f_0| \gg \Delta f,
\end{align}

where $f$ is a real part of the eigen 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 if Q-factors are much less than:

\begin{align}
  Q^* = f_0 / \Delta f.
\end{align}

The conditions (1-2) are satisfied, in particular, if the cavity has spectrum of eigen modes consisted of the quasi-degenerated modes. This situation takes place in the solution presented in [2].

In order to test at low power level the idea of compact pulse compressor, the cavity with the shape, shown in Fig. 1, was chosen. The transmission and reflection characteristics of the delay line consisted of this chain are plotted in Fig. 2. Near the operating frequency the reflection is less than 1% on power. The dependence of the phase on frequency is practically linear one (Fig. 3). This means that the incident pulse has delaying only (23 ns/m) without distortions on amplitude and phase.
corresponded the Fig. 1. The coupling diaphragm before the first cavity was calculated separately in order to provide maximal efficiency under compression ratio 5.

Figure 4: Scheme of the tested 4-cell pulse compressor.

The observed compression of 200 ns pulse without phase modulation (Fig. 5) as well as compression with the switched step-type phase modulation on (Fig. 6) is in good agreement with the theory. The power gain is ~2.2 without phase modulation, the power gain is about 4.5 with the π step-type phase modulation.

Figure 5: Experimental plot of the input (blue) and output (red) pulses formed by the compressor (no phase reverse).

Figure 6: Experimental plot of the input (blue) and output (red) pulses formed by the compressor (with phase reverse).

In order to provide maximal compactness, it is natural to increase the diameter of delaying cavity and simultaneously to reduce the length. A compressor assembled of cavities of such design usually requires more cells, but total length is reduced dramatically. The results of such calculations are summarized at Table 1. Designations of sizes are plotted in Fig. 7.

Table 1: Parameters of the calculated cavities scaled to 34.27 GHz

<table>
<thead>
<tr>
<th>Name</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 cavity</td>
<td>14.7</td>
<td>129</td>
<td>18</td>
<td>89.2</td>
<td>22.9</td>
<td>0.13</td>
</tr>
</tbody>
</table>

“Long” cavity

|        | 5  | 100 | 14   | 69.3  | 52.8            | 0.16                         |

“Short” cavity

Figure 7: Sizes of the calculated cavities.

Obviously, in order to obtain most compact design, it is necessary to expand the volume of cavity. However, volume expansion means an appearance of additional eigen modes which can spoil delaying without distortion of the pulse shape. Nevertheless, the mentioned problem is solvable. There are cavities, which have the pure degenerated eigen modes only. Any frequencies between groups of these degenerated modes are free of undesirable eigen modes and could be used for compression. These are so-called two-mirror confocal cavities. In geometry-optical approach all eigen modes of them are strictly degenerated.

**ONE-CHANNEL SLED-II PULSE COMPRESSOR**

The principal idea of the one-channel SLED-II pulse compressor, based on a ring-like cavity, is illustrated by means of the Fig. 8. The operating mode of the axis-symmetrical cavity consists of mode B and mode C, which propagate toward each other. In particular, let us consider the compressor with \( B=\text{TE}_{01} \) and \( C=\text{TE}_{02} \). These modes are transformed each to other in the ends of the delay line by means of special reflecting converters (Fig. 9). The feeding wave A is to be the \( \text{TE}_{11} \) mode, which propagates through the mentioned converters without conversion into other modes. This is reached due smooth converter’s profile, which is not resonant for the \( \text{TE}_{11} \) mode.

Figure 8: General scheme of one-channel SLED-II pulse compressor.

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The transmitting TE\textsubscript{11} mode is coupled selectively with the forward TE\textsubscript{01} mode only by means of the serpent-like periodic mode converter placed in the delay line (Fig. 10). This converter should provide optimal mutual TE\textsubscript{11}-TE\textsubscript{01} conversion in order to obtain high compression efficiency. Note that the backward TE\textsubscript{02} mode should be not perturbed by the coupling converter. The mentioned conditions are achievable due to relatively small periodic deformation of walls.

![Figure 10: TE\textsubscript{11}-TE\textsubscript{01} (forward modes) mode coupler.](image)

The Figs 11-12 describe results of calculation of the 34.27 GHz pulse compressor. The first figure shows mode behavior at the TE\textsubscript{01}-TE\textsubscript{02} mode reflector. At the operating frequency of the compressor the mutual conversion is about 99%. The TE\textsubscript{11} mode is transmitted through this reflector with efficiency 99%. For the compression ratio 4, the optimal coupling is 50% on power. That is why, in Fig. 12 mutual conversion of TE\textsubscript{11} and TE\textsubscript{01} modes reaches this value at the operating frequency.

![Figure 11: Calculation of modes at the TE\textsubscript{01}-TE\textsubscript{02} mode reflector.](image)

![Figure 12: Calculation of the mode coupler with coupling coefficient 0.5 on power.](image)

The mentioned modes \( A, B, \) and \( C \) could be arbitrary. For example, scheme with pure axisymmetrical modes \( (A=TE_{01}, \ B=TE_{02}, \ C=TE_{03}) \) seems attractive.

### COMPRESSORS BASED ON MULTI-MIRROR DELAY LINES

At high frequencies the use of mirror lines becomes more natural in comparison with the closed waveguide delay lines. The mirror lines are capable to provide low-loss transmission and good compactness. The suppression of the reflected power, propagating in backward direction to the incident RF source, is achieved by means of diffraction grating (Fig. 13).

In Fig. 13 the 30 GHz pulse compressor is shown which was calculated to provide 25 ns duration of the output pulse. The total height of the compressor in vertical direction is \(-1800\) mm \((2a=520\) mm, \(b=426\) mm, \(\phi=55^\circ)\). The sizes of the used mirrors are \(174\times143\) mm\(^2\). Each of two neighbor mirrors represents a so-called confocal pair.

![Figure 13: SLED-II pulse compressor based on multi-mirror delaying line.](image)

### CONCLUSION

The SLED-II pulse compressor, based on TE\textsubscript{0n} mode cavity chains allow to reduce up to 50 times the length of delaying lines in comparison with usual delay lines.

The one-channel TE\textsubscript{01}-TE\textsubscript{02} SLED-II pulse compressor is suggested. It does not require the 3 dB coupler.

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, really flat output pulse shape.

### REFERENCES
