$\text{TE}_{01}-\text{TE}_{02}$ DLDS Elements

BINP-KEK
Tap-off
(Local Distribution System)

Legend:

1:2 Power Splitter
1:1 Power Splitter
Phase Shifter
Accelerating Structure
TE10-TE01 Mode Converter
Oversize Waveguide
Main parameters of $\text{TE}_{01}-\text{TE}_{02}$ DLDS

- Number of modes: 2
- Operating modes: $\text{TE}_{01}, \text{TE}_{02}$
- Main waveguide diameter: 120 mm
- Node-to-node distance: 56.3 m
- $\text{TE}_{01}$ loss: $-0.001 \text{dB/m}$
- $\text{TE}_{02}$ loss (measured): $-0.004 \text{dB/m}$
- Average main waveguide loss of 4-node DLDS: 3.5%
TE_{01} - TE_{02} 2x2 DLDS system

8 Klystrons
75 MW, 120 Hz

Super Hybrid

Circular Waveguide (Ø 120 mm)

Tap-off System

TE_{02} Mode Extractor

Tap-off System

TE_{01} - TE_{02}
Mode Launcher
600 MW, 800 ns

6 m

56.3 m

56.3 m

56.3 m

RF Structure,
85 MW, 70 Mv/m
Basic Elements of TE$_{01}$-TE$_{02}$ DLDS

- H-Hybrid
- TE$_{10}$-TE$_{01}$ Converter
- TE$_{01}$-TE$_{02}$ Launcher
- TE$_{01}$-TE$_{02}$ Extractor
- 1:1 Power Splitter
- 1:2 Power Splitter
- 90° TE$_{01}$ Bend
- Phase Shifter
H-Hybrid. HFSS calculations.
H-Hybrid. High Power Model
H-Hybrid. Low power RF test results

Hybrid port #1 VSWR (S11)

Transmission between ports 1 – 2 (S12) and 1 – 4 (S14)
TE\textsubscript{10}-TE\textsubscript{01} Mode Converter

Output diameter  46 mm
Length  280 mm
TE$_{10}$-TE$_{01}$ Mode Converter. HFSS Calculations

S11

\[
\begin{array}{c|cccc}
\text{GHz} & 11.2 & 11.3 & 11.4 & 11.5 \\
\hline
\text{VSWR} & & & & \\
1.00 & 1.05 & 1.10 & 1.15 & 1.20 & 1.25 & 1.30 \\
\end{array}
\]

S12

\[
\begin{array}{c|cccc}
\text{GHz} & 11.2 & 11.3 & 11.4 & 11.5 \\
\hline
\text{S12, dB} & -0.1 & -0.2 & -0.3 & -0.4 \\
-0.5 & -0.4 & -0.3 & -0.2 & -0.1 & 0.0 \\
\end{array}
\]
$\text{TE}_{10}-\text{TE}_{01}$ Mode Converter. Low Power Model
TE\textsubscript{10}-TE\textsubscript{01} Mode Converter. Low power RF test results

SWR for the TE\textsubscript{01} Mode Converter

Transmission from the choke-type TE\textsubscript{01} converter (Ø40mm circular waveguide) to the tested TE\textsubscript{01} converter (Ø46mm circular waveguide) for tree angles between H-plane of the WR90 inputs of these converters.
$\text{TE}_{01}$-$\text{TE}_{02}$ Mode Launcher

$\text{TE}_{02}$ Mode Extractor
$\text{TE}_{01}\text{-TE}_{02}$ Launcher-Extractor. HFSS calculations.
TE_{01} - TE_{02} Mode Launcher

TE_{02} Mode Extractor
TE_{01}-TE_{02} Mode Launcher-Extractor. HFSS calculations.

\[ E_{\text{max}} = 480 \text{kV/cm} \text{ for 600MW} \]
Part of $\text{TE}_{01}-\text{TE}_{02}$ Launcher-Extractor
$\text{TE}_{01}$-$\text{TE}_{02}$ Mode Launcher-Extractor. Low Power RF Model
$\text{TE}_{01}-\text{TE}_{02}$ Mode Launcher-Extractor plus Overmodded Tapers.
$TE_{02}$ Mode Launcher and Extractor. Low Power RF Test Setup.
**TE_{01}-TE_{02} Mode Launcher-Extractor. Low power RF test results.**

VSWR of the TE_{01}-TE_{02} Launcher

![Graph showing VSWR of TE_{01}-TE_{02} Launcher](image)

VSWR of the TE_{02} Mode Extractor

![Graph showing VSWR of TE_{02} Mode Extractor](image)
**TE\textsubscript{01}-TE\textsubscript{02} Mode Launcher-Extractor. Low power RF test results.**

Isolation between port #1 and port #2 for the TE\textsubscript{01}-TE\textsubscript{02} Launcher

Isolation between port #1 and port #2 for the TE\textsubscript{02} Mode Extractor
TE$_{02}$ Mode Extractor. Low power RF test results.
TE\textsubscript{01}-TE\textsubscript{02} Mode Launcher-Extractor. Low power RF test results.

Transmission from the TE\textsubscript{01}-TE\textsubscript{02} Launcher port #1 to the TE\textsubscript{02} Extractor port #1 and port #2

Transmission from the TE\textsubscript{01}-TE\textsubscript{02} Launcher port #2 to the TE\textsubscript{02} Extractor port #1 and port #2
1/2 TE_{01} Power Splitter. HFSS Calculations.
1/2 $\text{TE}_{01}$ Power Splitter. Low Power RF Model.
1/2 $\text{TE}_{01}$ Power Splitter. Low Power RF Test Results.

SWR of the $\frac{1}{2} \text{TE}_{01}$ Power Splitter
Squared transmission coefficient $S_{12}$ for the TE$_{01}$ 1/2 Power Splitter for two angles between H-plane of WR90 input of the TE$_{01}$ converter and WR90 output #2 of the tested splitter.

Squared transmission coefficient $S_{12}$ for the TE$_{01}$ 1/2 Power Splitter for two angles between H-plane of WR90 input of the TE$_{01}$ converter and WR90 output #3 of the tested splitter.
1/3 $\text{TE}_{01}$ Power Splitter. HFSS Calculations
1/3 $\text{TE}_{01}$ Power Splitter. Low Power RF Model.
1/3 $TE_{01}$ Power Splitter. Low Power RF Test Results.

SWR of the 1/3 $TE_{01}$ Power Splitter
Squared transmission coefficient $S_{12}$ for the TE$_{01}$ 1/3 Power Splitter for two angles between H-plane of WR90 input of the TE$_{01}$ converter and WR90 output #2 of the tested splitter.

Squared transmission coefficient $S_{12}$ for the TE$_{01}$ 1/3 Power Splitter for two angles between H-plane of WR90 input of the TE$_{01}$ converter and WR90 output #3 of the tested splitter.
90° TE₀₁ Bend. HFSS Calculations.
90° $\text{TE}_{01}$ Bend. Low Power RF Model.
90° TE₀₁ Bend. Low Power RF Test Results.

**Transmitted Power, [%]**

- **Frequency, [GHz]**
  - 11.30
  - 11.35
  - 11.40
  - 11.45
  - 11.50
  - 11.55
  - 11.60

**Undesirable modes composition at the output of TE₀₁ 90-degree Bend**

- TE₁₁ mode
- TE₂₁ mode
- TE₃₁ mode
Quasi-pulse measurement with long pipe

The measurements of propagation of pure TE01 and TE02 modes.

Measurements layout:
Layout in tunnel:
Result of measurements:

TE01 one-way efficiency 98.54%
TE02 one-way efficiency 95.20%

Loss:
TE01 - 1.46% (theory 1.18%)
TE02 - 5.75% (theory 4.31%)
Measurements of TE01-TE02 Launcher-Extractor performances
‘No long pipe’ setup:
Results of measurements

Measured efficiency of launching and extraction of $\text{TE}_{01}$ mode 97.1%
Measured efficiency of launching and extraction of $\text{TE}_{02}$ mode 97%

Theoretical estimated efficiency 97%
Measurements with long pipe.