Implementing a Near-Optimal Optical Receiver for Interplanetary Communications

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NASA
Overview

• Spatial Encoding Joint Detection Receiver (JDR)

• Temporal Encoding JDR

• Ultrafast Coherent All-Optical Switching

• Receiver Architecture
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Photon Information Efficiency (PIE)

Performance of the BPSK Hadamard code with the Green Machine JDR: exceed the single-symbol receiver PIE
Approaching The Holevo Limit

JDR architecture which improves efficiency for low-light level signals.

Simple design

No feed-forward required

\[ |\alpha|^2 \ll 1 \]

Coherent state signals

DPSK Hadamard Code

PPM code

Approaching The Holevo Limit
Approaching The Holevo Limit
Issues With Multiple Spatial Modes

Non-uniform phase accumulation over channels

Overlap of spatial modes after long propagation distance
Single Spatial Mode Transmission

Uniform Phase Accumulation,

For Sufficiently Small Blocks of Temporally Encoded Data
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Bitwise Binary Switch

Selecting individual temporal modes

\[ S^{(n)}(t) : \text{alters switching behavior} \]

\[ \text{In}_0 \rightarrow \text{Out}_0 \quad \text{In}_0 \rightarrow \text{Out}_1 \]
Bitwise Binary Switching
Bitwise Mode Interference
Bitwise Mode Interference
Bitwise Mode Interference

1 detector, \( N \) switches, \( N \) beamsplitters

**Requirements for switching device**

- low loss
- low in-band noise
- high speed
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All-Optical Coherent Switch

Temporal modes

Control Pump Out

In₀ → Circ → Out₀

Control Pump In

In₁ → Circ → Out₁

Oza et al., Frontiers in Optics, FThL7 (2011)
Patel et al., IEEE Summer Topical Meeting Series p 16-17, July 2011
Switch Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching Rep Rate</td>
<td>1 GHz 50 MHz</td>
</tr>
<tr>
<td>Switching Window</td>
<td>30ps</td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>0.5 dB</td>
</tr>
<tr>
<td>In Band Noise</td>
<td>$\leq 10^{-4}$ Photons/Pulse</td>
</tr>
</tbody>
</table>
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Bitwise Optical Switching

Bitwise switching can be realized...

by appropriately modulating the control pulses
Bitwise Mode Interference

The temporal JDR…

can be constructed from these optical switches
Acknowledgements

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Thanks For Listening