The Challenge of Time Distribution: Free space or optical fibre?

Dedicated to:
Guglielmo Marconi and Charles Kao

1909
Nobel Laureates in Physics
Wireless and optical fibres

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The power of light
Who needs a stable time/phase reference?

- GPS systems, synchronous data networks, cell phone telephony, time stamping financial trades
- Large scale interferometers for telescopes
- Optical gyroscopes

Who needs minimum latency/transit time?

- Data centres/computer interconnects
- Financial traders

You can't beat vacuum for loss, speed of light or stability!
Very large interferometers:
Increase the resolution of astronomical telescopes

The Very Large Telescope Interferometer (VLTI) on Paranal Mountain
Data Centre Interconnection

Information flow/unit area and latency is key in supercomputers and data centres

20,000 km of fibre per data centre in Facebook alone!

Vacuum transit time is 30% lower
Optical Fibre Gyroscopes

- High-performance: applications in inertial guidance, navigation, platform stabilization, GPS flywheeling, etc.
- Lower-performance: Consumer / industrial applications in

Performance limited by glass core
Introducing the vacuum waveguide: Hollow-Core Microstructured Fibres

Periodic lattice of holes

Advantage: Typically less than 0.1% optical power in cladding. Ultra-low nonlinearity, lower loss?
Vacuum fibre technology
Fibres that largely ignore the materials from which they are made

- Power in glass < 0.01% → low nonlinearity
- Transmission loss < 0.01 dB/m
- Phase insensitive
- Radiation hard
- IR transmitting

As you would expect from vacuum!
The new anti-resonant fibre
Low Latency data communications

- Data transmission at 99.7% the speed of light in vacuum
- ‘Only’ 69.4% in a conventional fibre

Latency savings
(vs conventional fibres):

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Latency (ns/µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.54 ns</td>
</tr>
<tr>
<td>100</td>
<td>154 ns</td>
</tr>
<tr>
<td>1</td>
<td>1.54 µs</td>
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<tr>
<td>100 km</td>
<td>154 µs</td>
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</tbody>
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Phase Insensitive Fibres

The phase of a signal in a fibre changes with temperature owing to:
- Change in refractive index
- Change in fibre length

- Vacuum fibre temperature sensitivity 2 ps/km/K
- 18.5 times smaller than conventional fibres

Dr Radan Slavik
Dr Eric Numkam

Slavik et al., Scientific Reports 2015.
Air-core fibre for speed-of-light trading
A huge financial opportunity?