



ITU Kaleidoscope 2016
ICTs for a Sustainable World

**SPACE DIVISION MULTIPLEXING TECHNOLOGY:
NEXT GENERATION
OPTICAL COMMUNICATION STRATEGY**

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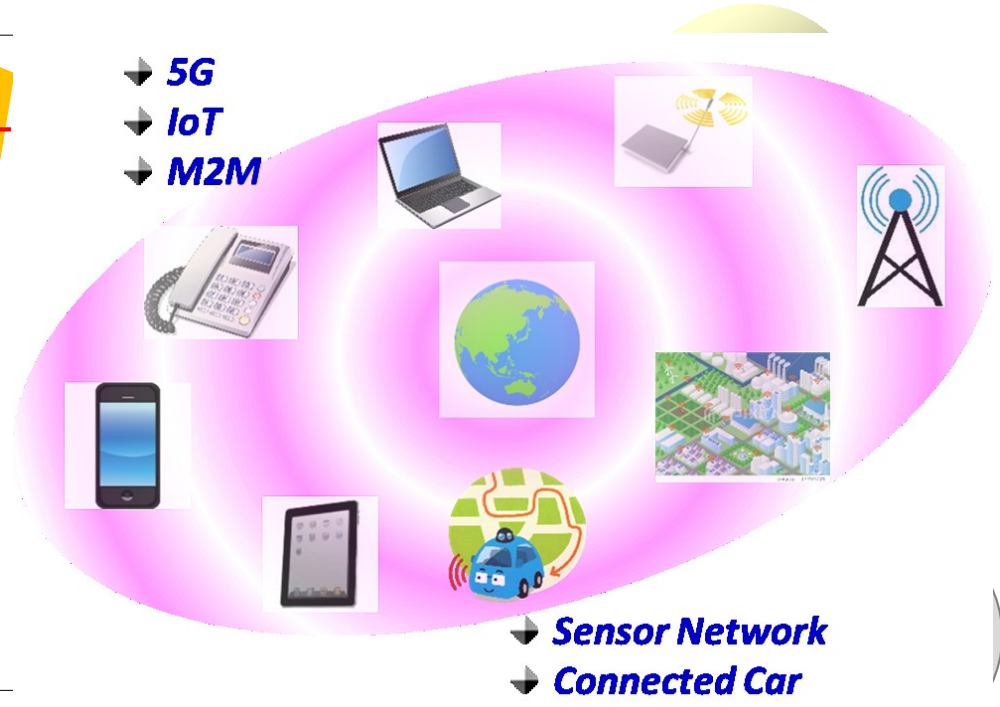
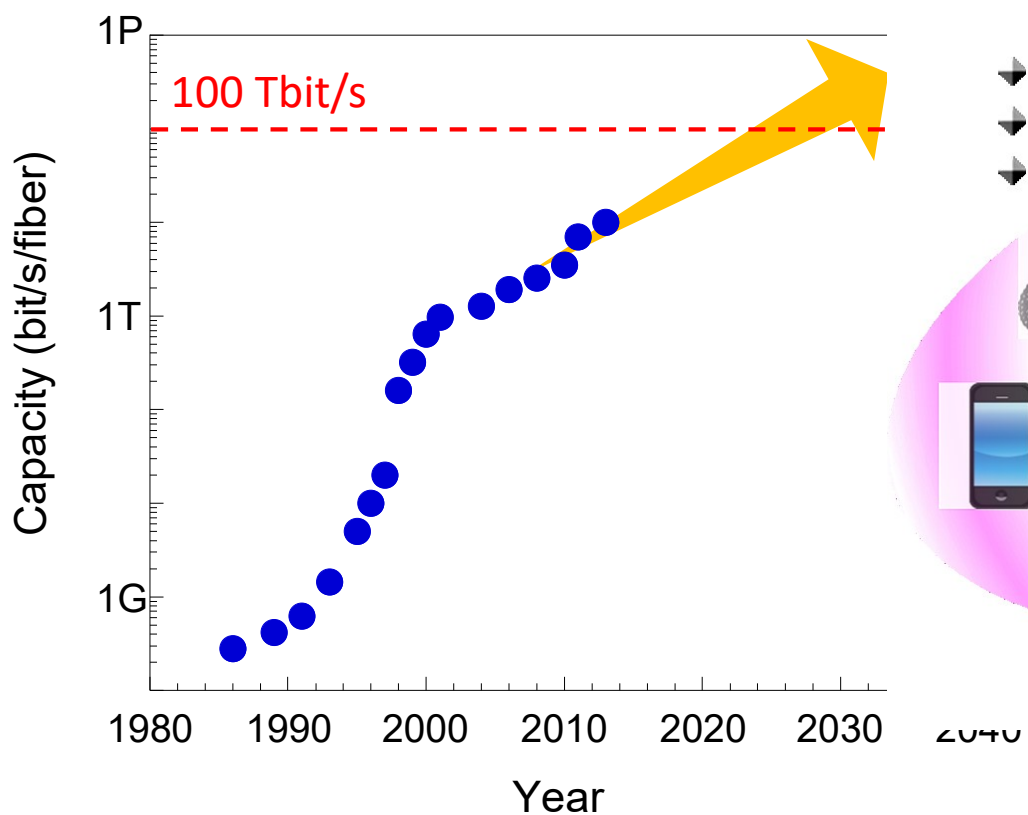
Bangkok, Thailand
14-16 November 2016

- ✓ Why we need space division multiplexing (SDM)?
 - *Two major reasons*
- ✓ SDM in optical fibre cable
 - *Available spatial dimensions & scalability of multi-core fibre (MCF)*
- ✓ Standardization of MCF technology
 - *Example milestone & key technologies*
- ✓ Conclusion

Reason 1: Capacity crunch



- **Backbone NW will require >100 Tbit/s in late 2020s**
- **Maximum bandwidth of SMF is limited to around 100 Tbit/s**

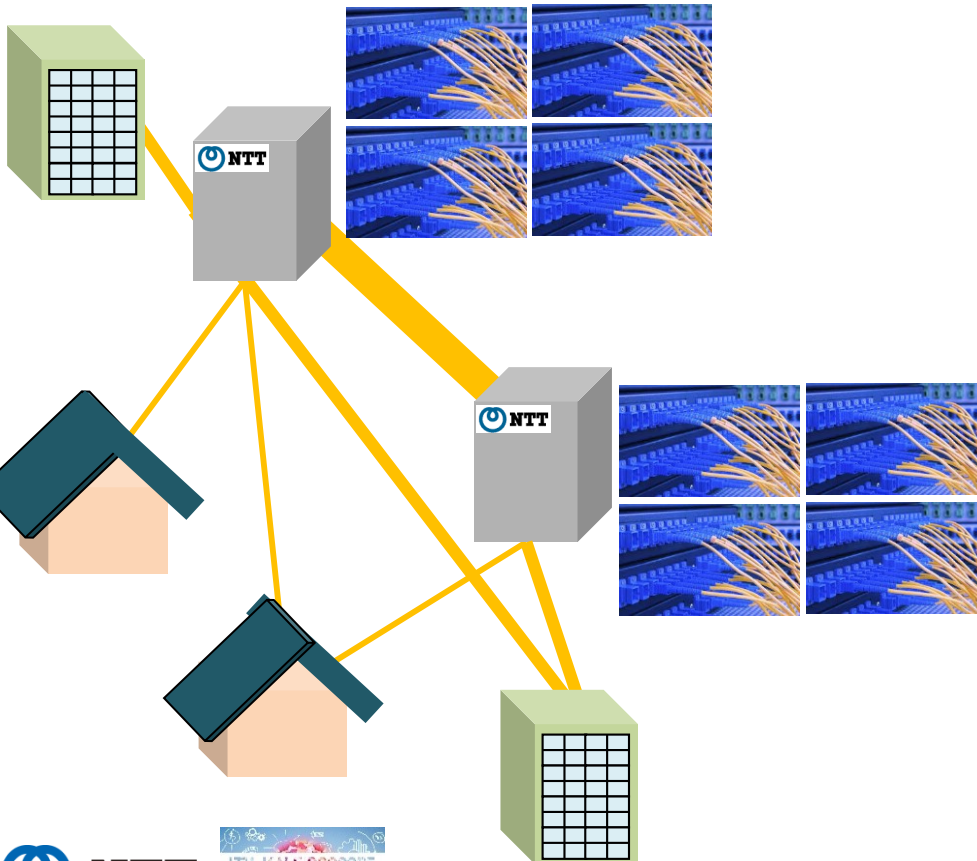


[<http://jpn.nec.com/techrep/journal/g15/n03/pdf/150316.pdf>]

Reason 2: Fibre conjunction in CO & DC



- Spreading optical network requires plenty of connection and wiring space
- N -space multiplexing directly realizes N^1 -space saving



SDM based high-density connection and wiring





Innovative R&D by NTT

SDM as mandatory strategy

- **SDM enables power efficient transmission system**
- **SDM realizes future transmission system in a sustainable manner**

Optical submarine system

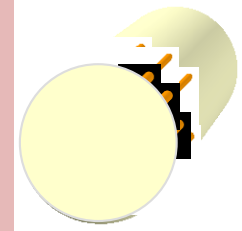
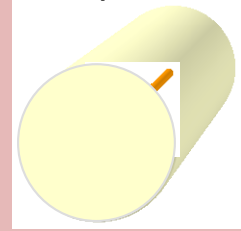


Maximum capacity

under limited pump power

SMF w/ EDFA

12-core & 12-EDFA



<

36 Tbit/s

105 Tbit/s × 14350 km

[OFC'16, Th4C.1]

More space

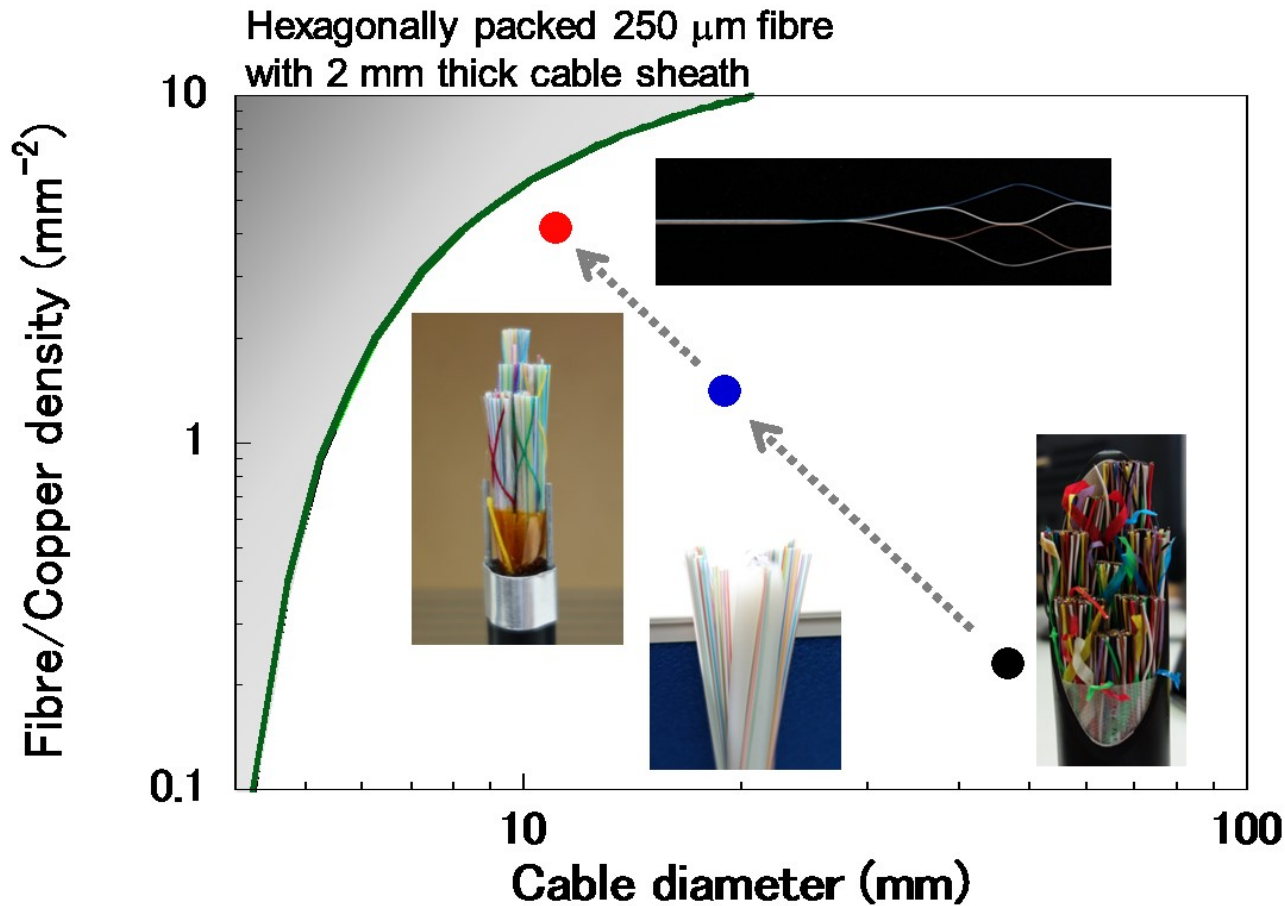
Limited power

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High density cable can solve the problems?



- Cable density is approaching the geometrical limit
- Additional cable requires further physical infrastructure & cost

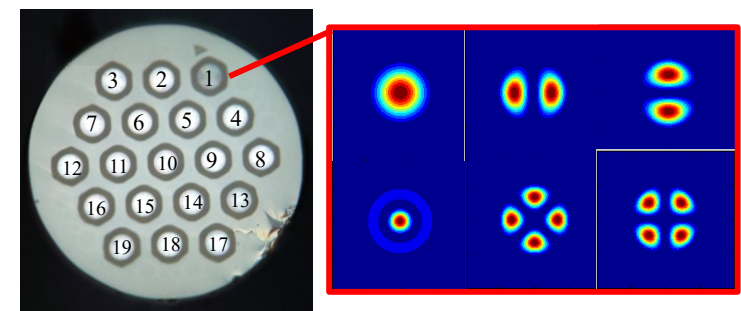
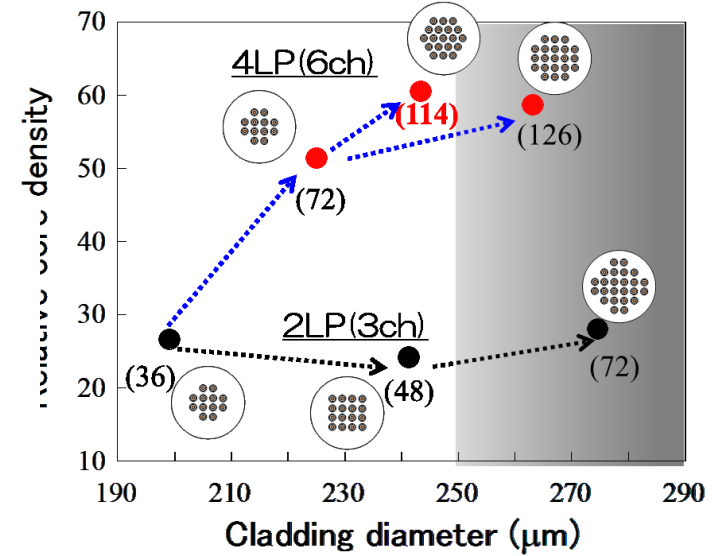
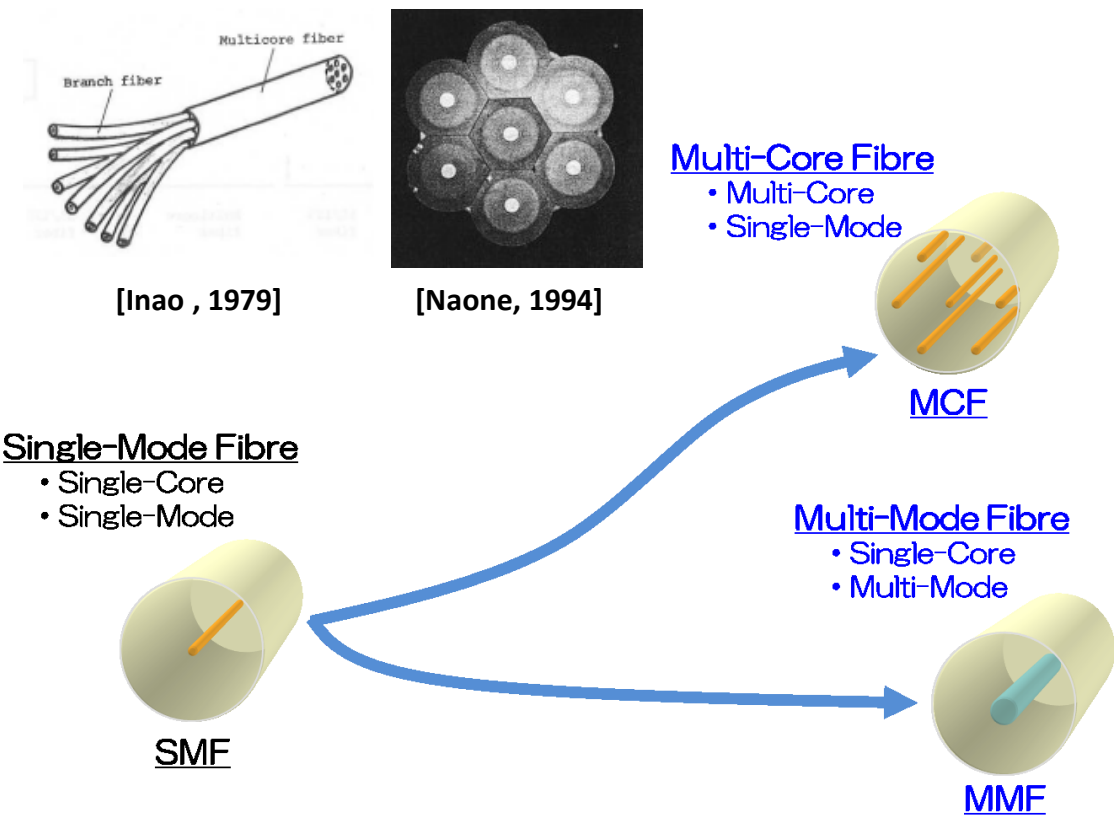


SDM in optical fibers



- Optical fibre has been tailored in two dimensions, core and mode
- MCF can easily employ the single-mode technology

➤ Pioneer work on multi-core fiber

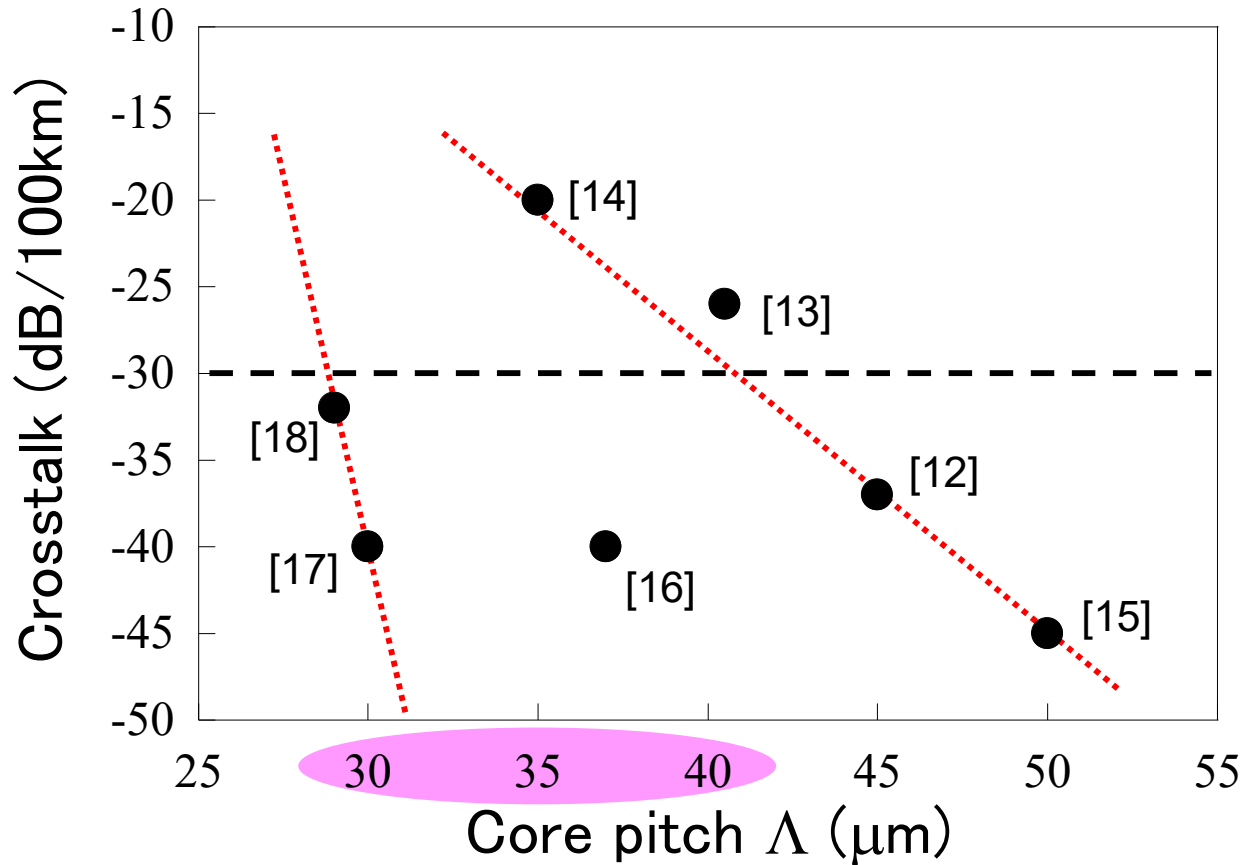


Design of MCF



Innovative R&D by NTT

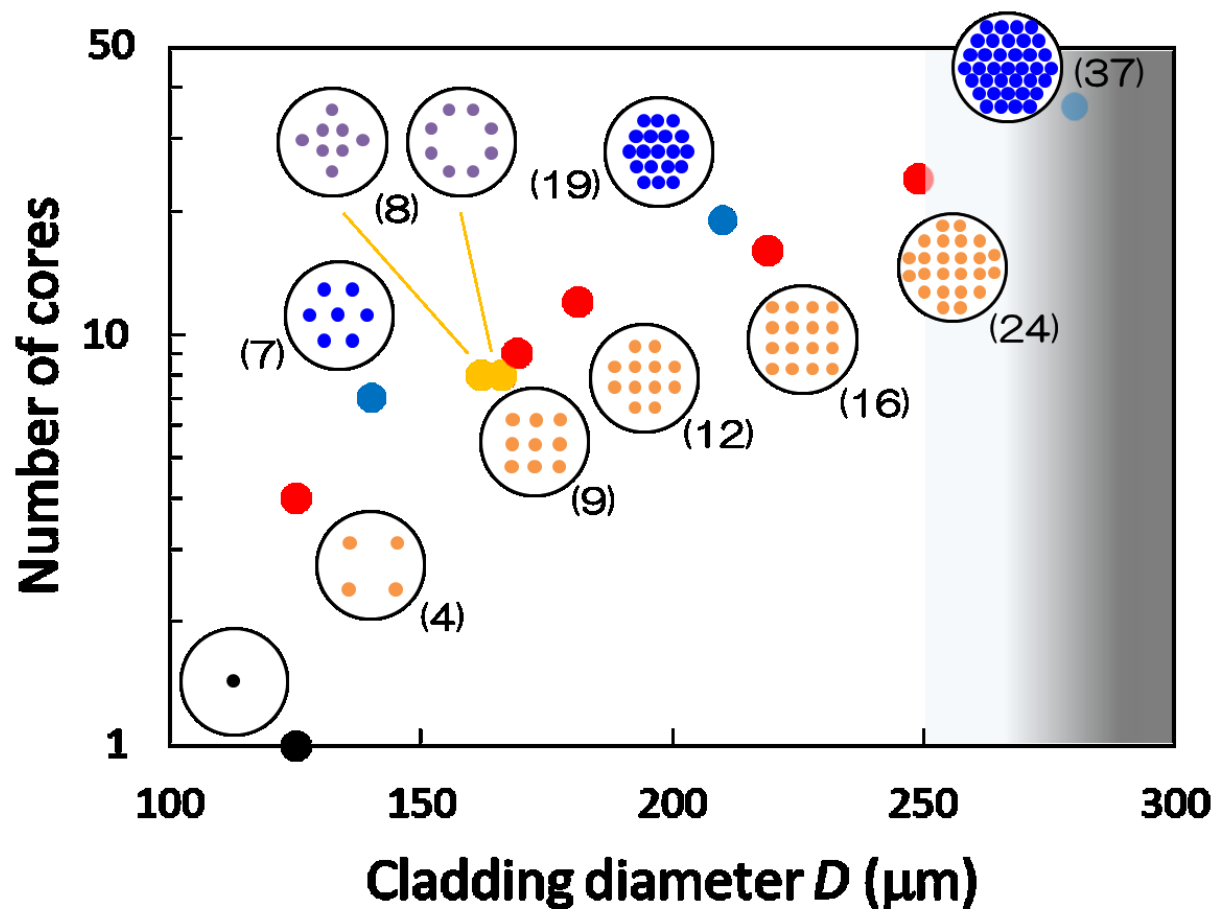
- MCF has three key geometrical parameters, D , t & Λ
- MCF with adequate geometrical parameter can provide considerable meaning in terms of spatial multiplexing



Scalability of MCF



- A $35\ \mu\text{m}$ Δ & t enable us to tailor 20 to 30 cores in terms of the cladding diameter and core arrangement

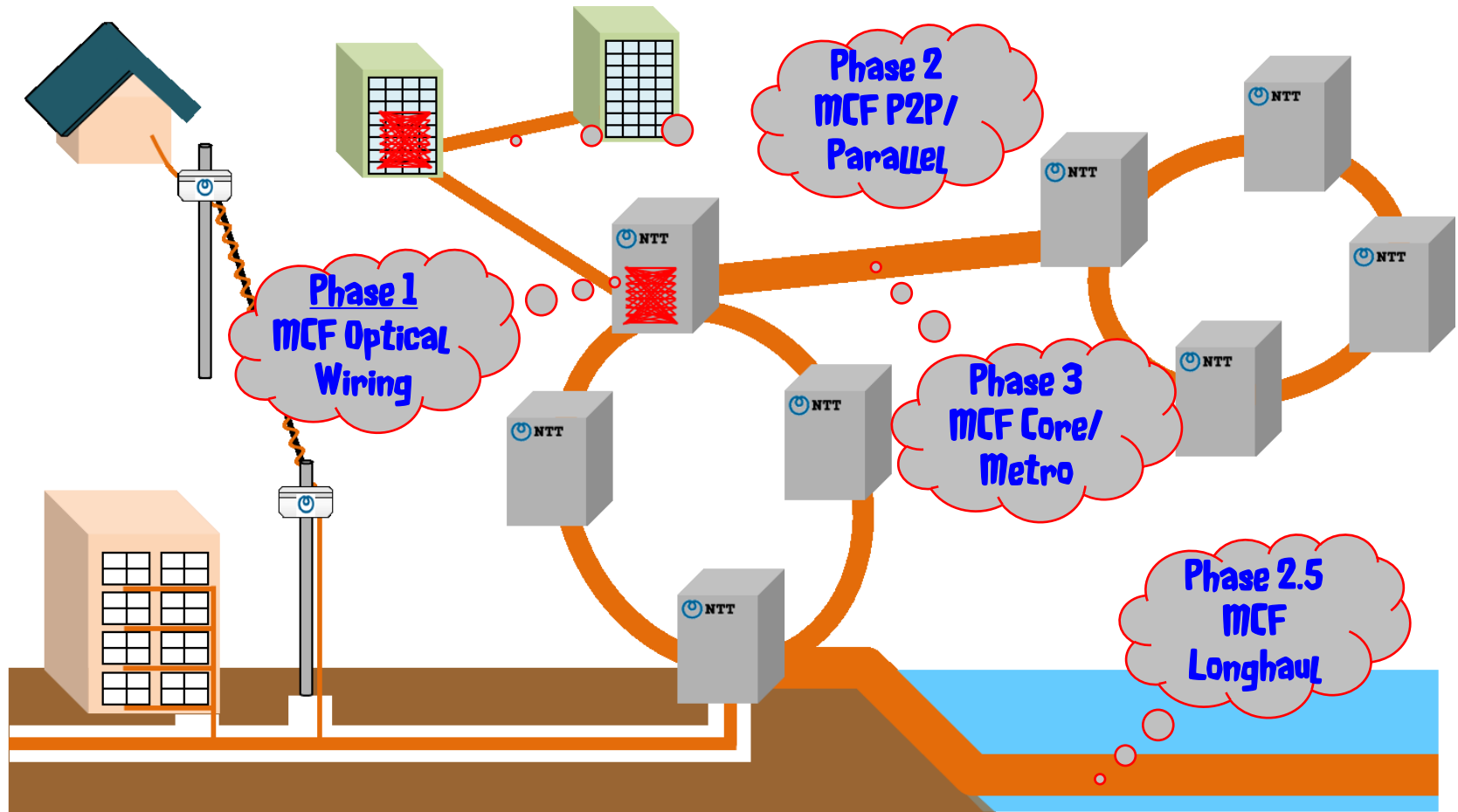


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Spreading phase of MCF



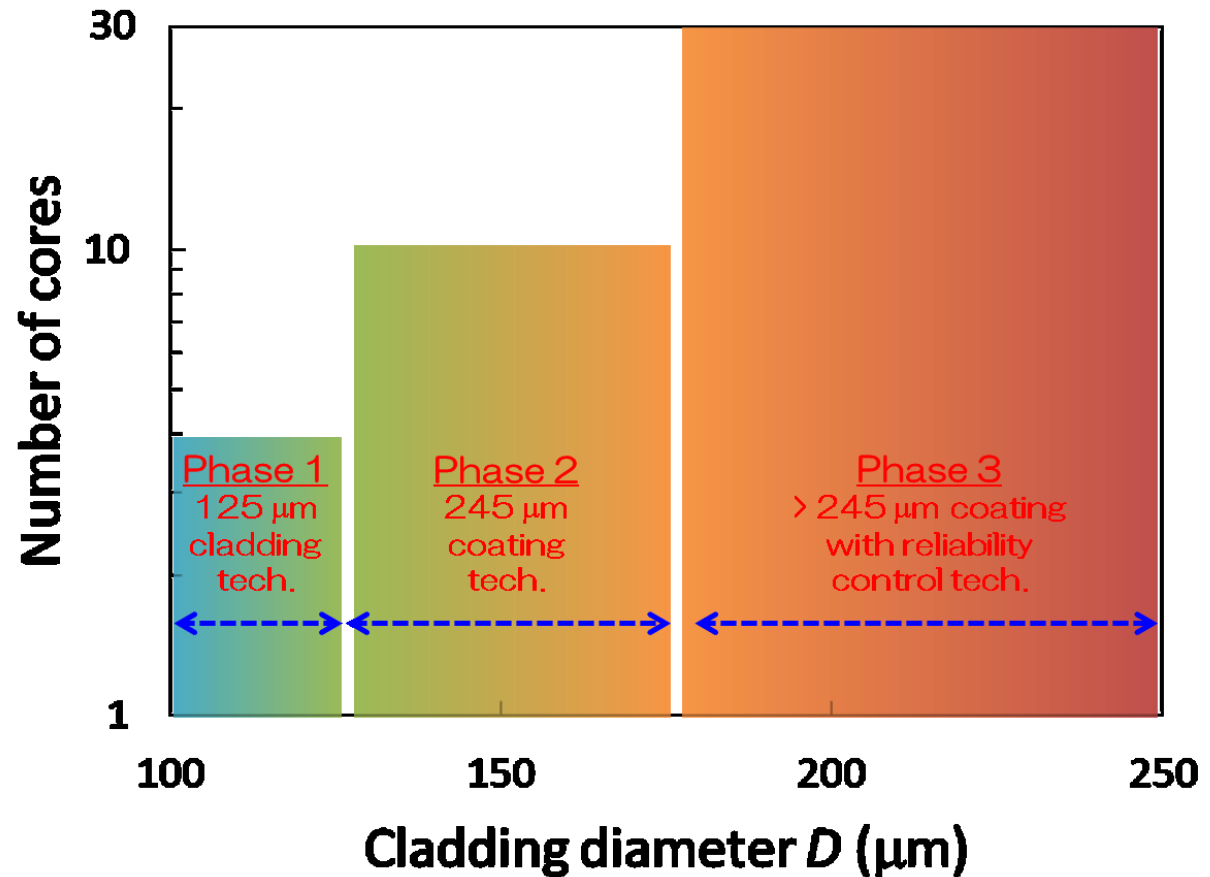
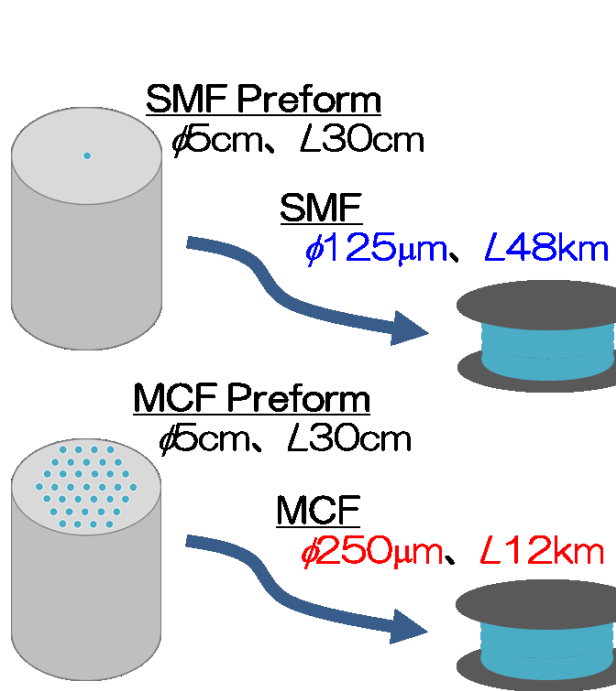
➤ MCF optical wiring can be considered as the first deployment rather than MCF core/metro transmission



Mass-producibility of MCF



- A breakthrough is essential for realizing a long thick MCF
- A tiered approach to both application area and cladding diameter support the smooth and effective deployment of MCF



Key technology for MCF application



- **SDM optical wiring requires:**
Standard optical fiber & Connector/splicing & Cable/wiring

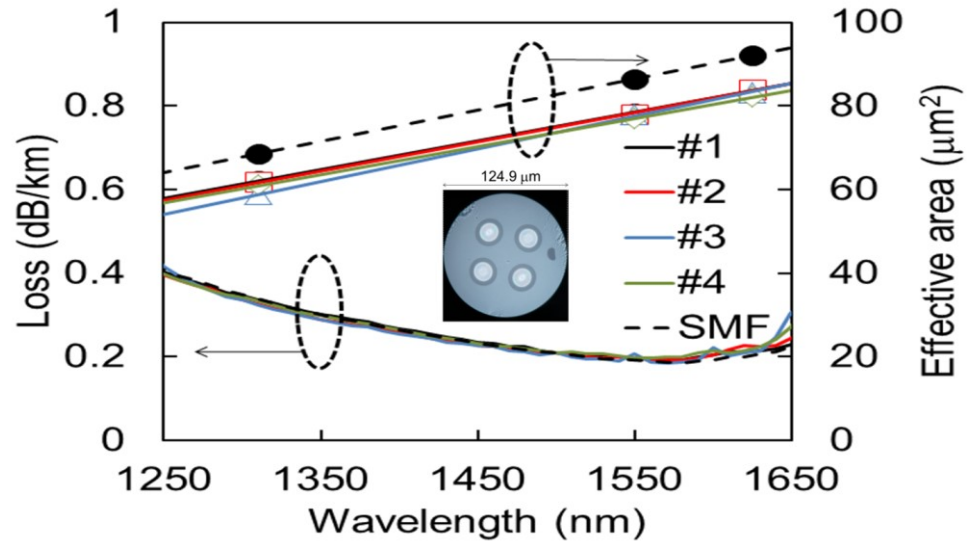
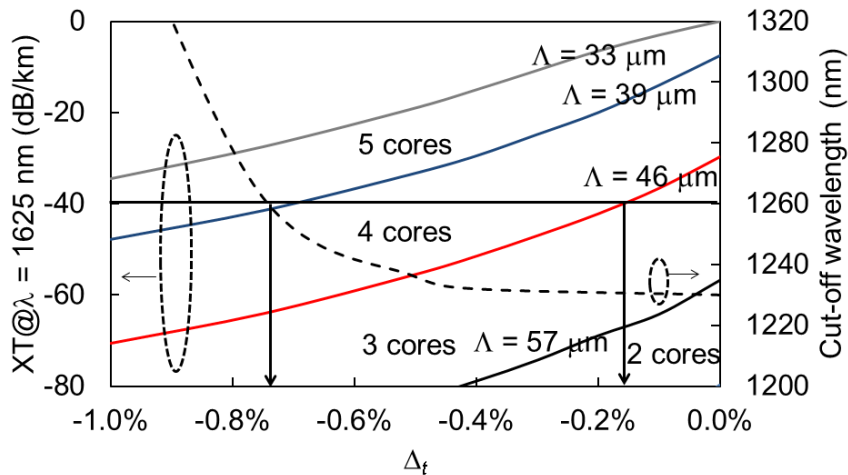
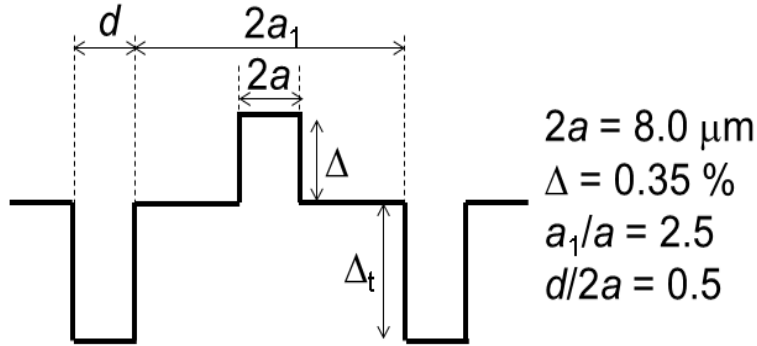
Phase & Application Area	Key Technology
1. SDM optical wiring in CO/DC	MCF with standard properties Connector and splicing Cabling and wiring
2. Long-haul point to point transmission system	245 μm coating SDM fibers Optical amplifier Power efficient system design
3. Terrestrial metro/core optical link	Cost effective fiber fabrication Optical node/switching

MCF with standard properties



➤ Trench profile enables four-core in a 125 μm cladding diameter while keeping full compliance to conventional SMF

MCF with full compliance to SMF



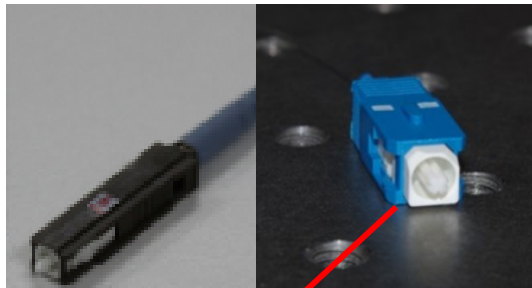
Optical property	Compliance to G.652
Attenuation	✓
Mode-field diameter	✓
Cutoff wavelength	✓
Chromatic dispersion	✓
Macrobending loss	✓

Connector & splicing technology

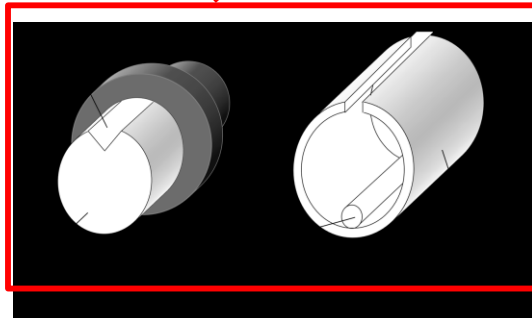


- Standard connectors can be utilized to MCF
- Side view technique enables automatic angle alignment of MCF

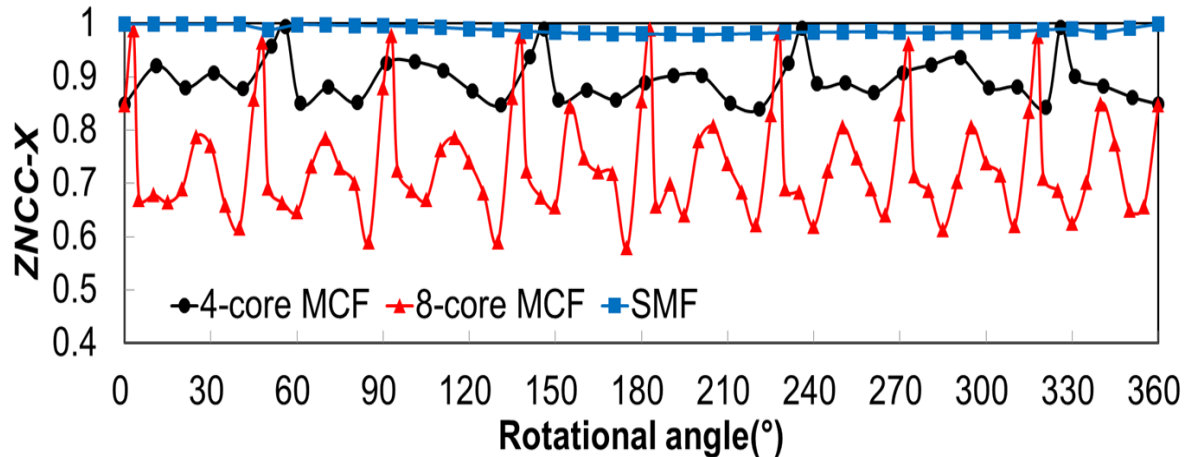
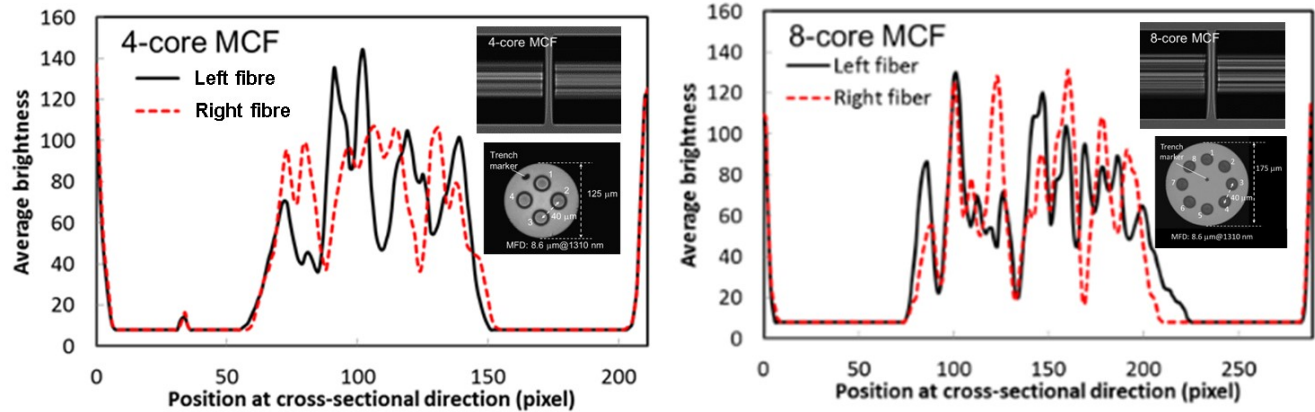
MU & SC connectors with precise angle alignment mechanism



[Prof. Nagase] [OECC'14, p. 872]



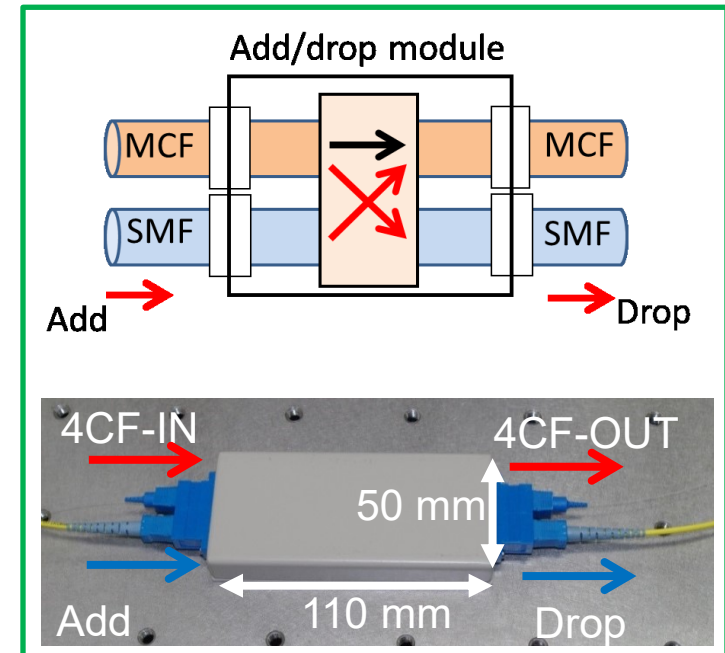
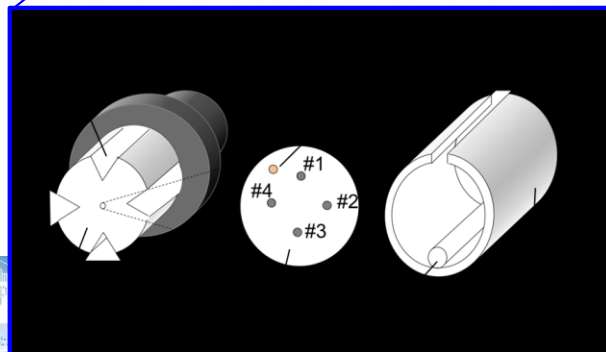
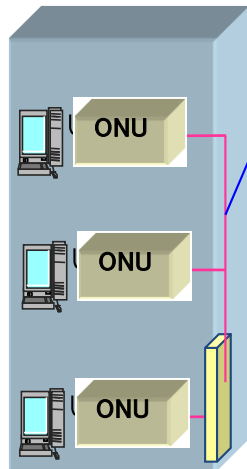
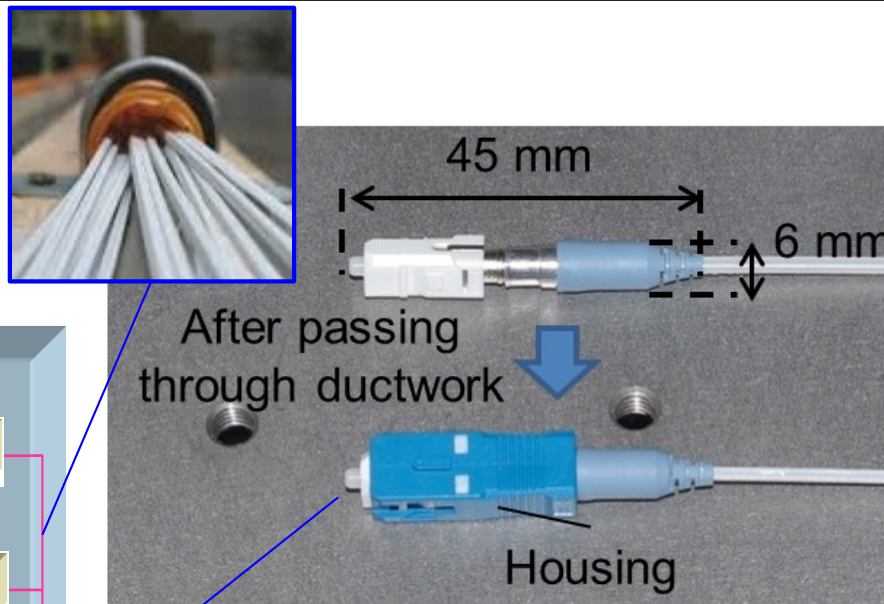
Fusion splicing based on side view monitoring



Cabling & wiring technology



- **Manufactured mini-connector enables flexible wiring**
- **Combination of rotatable SC connector & PLC module enables to construct pluggable add/drop link**



Pluggable add/drop link

[IWCS'16, 13-6]

- ✓ *SDM is the mandatory strategy for future optical communication system*
- ✓ *A tier approach supports smooth & effective spread of MCF application*
- ✓ *Three key technologies, MCF with standard property, connector & splicing, and cabling & wiring, are ready for discussing the real application of MCF*