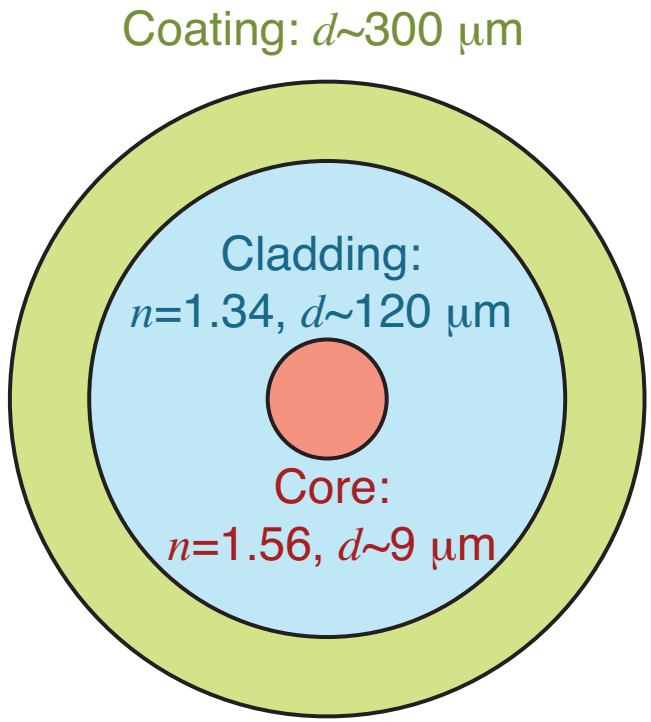
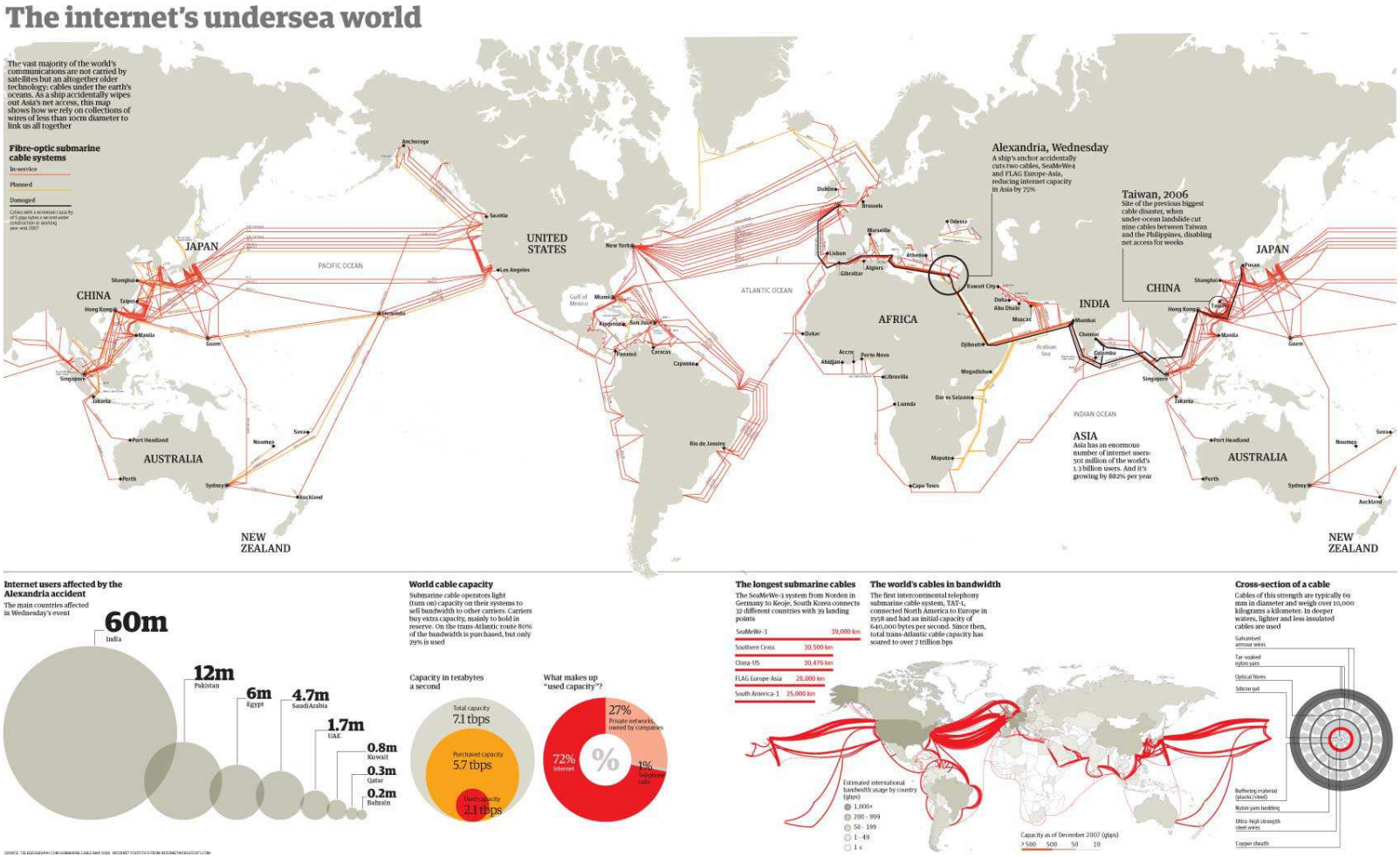
Single mode optical fibers

- Theoretical description of required characteristics (single mode, < 10 db/km loss): C.K. Kao, 1964.
- Corning patent and demonstrations (R. Maurer, D. Keck, P. Schultz): 1970–1972.
- Improved manufacturing scheme at Bell Labs (J. MacChesney): 1973.
- First deployments (Long Beach, Chicago; 0.006 Gbit/s): 1977.
- First transatlantic cable (TAT-8, 5600 km, $335M, amplifiers every 40 miles; 0.020 Gbit/s): 1988
- Today: bit rates up to 14 000 Gbit/s over 160 km lines.



Undersea fiber optics



January 30, 2008: a ship cuts off parts of the middle east and east asia by dragging its anchor across an undersea cable! See

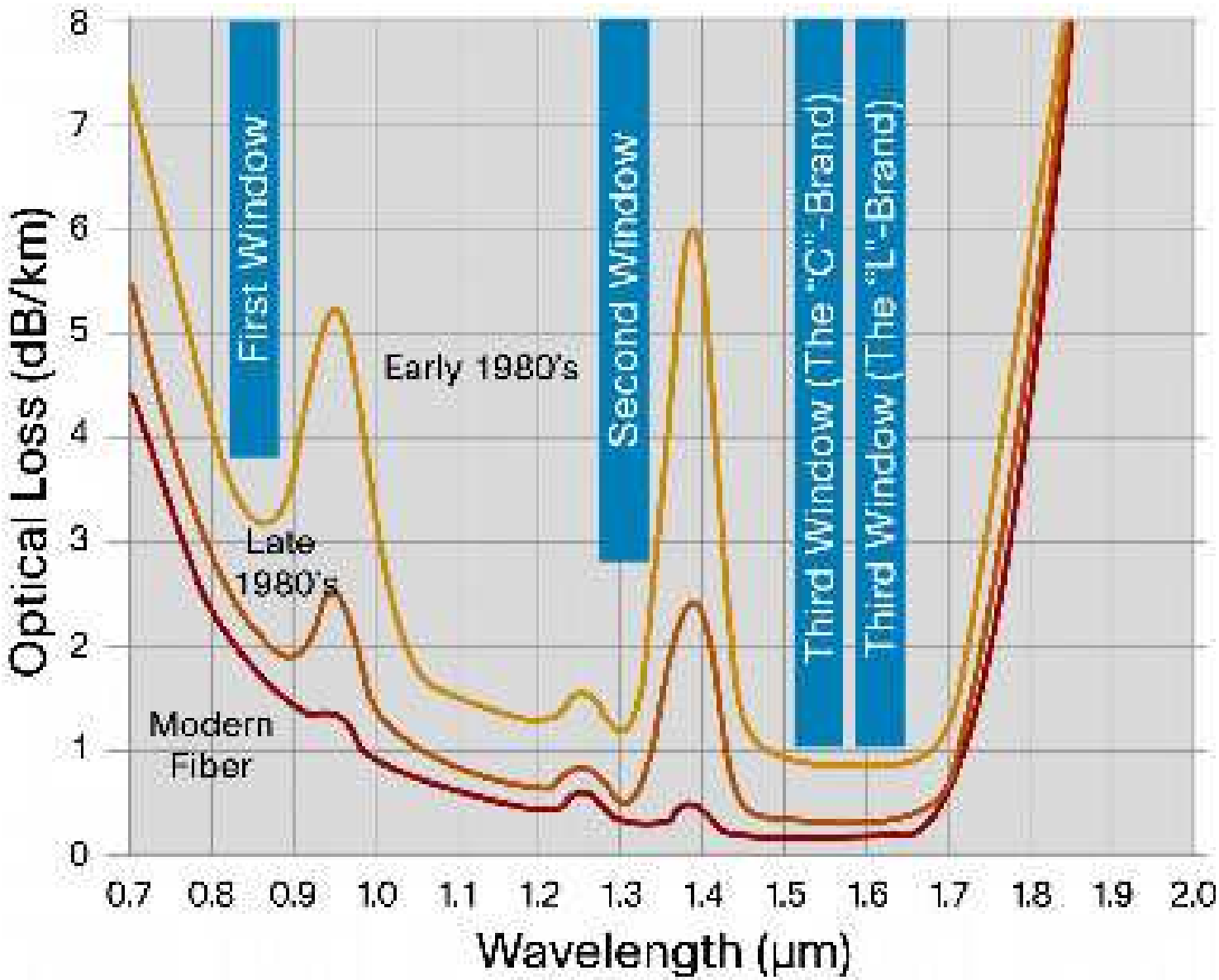
http://www.guardian.co.uk/business/2008/feb/01/internationalpersonalfinancebusiness.internet

Manufacturing fiber optics

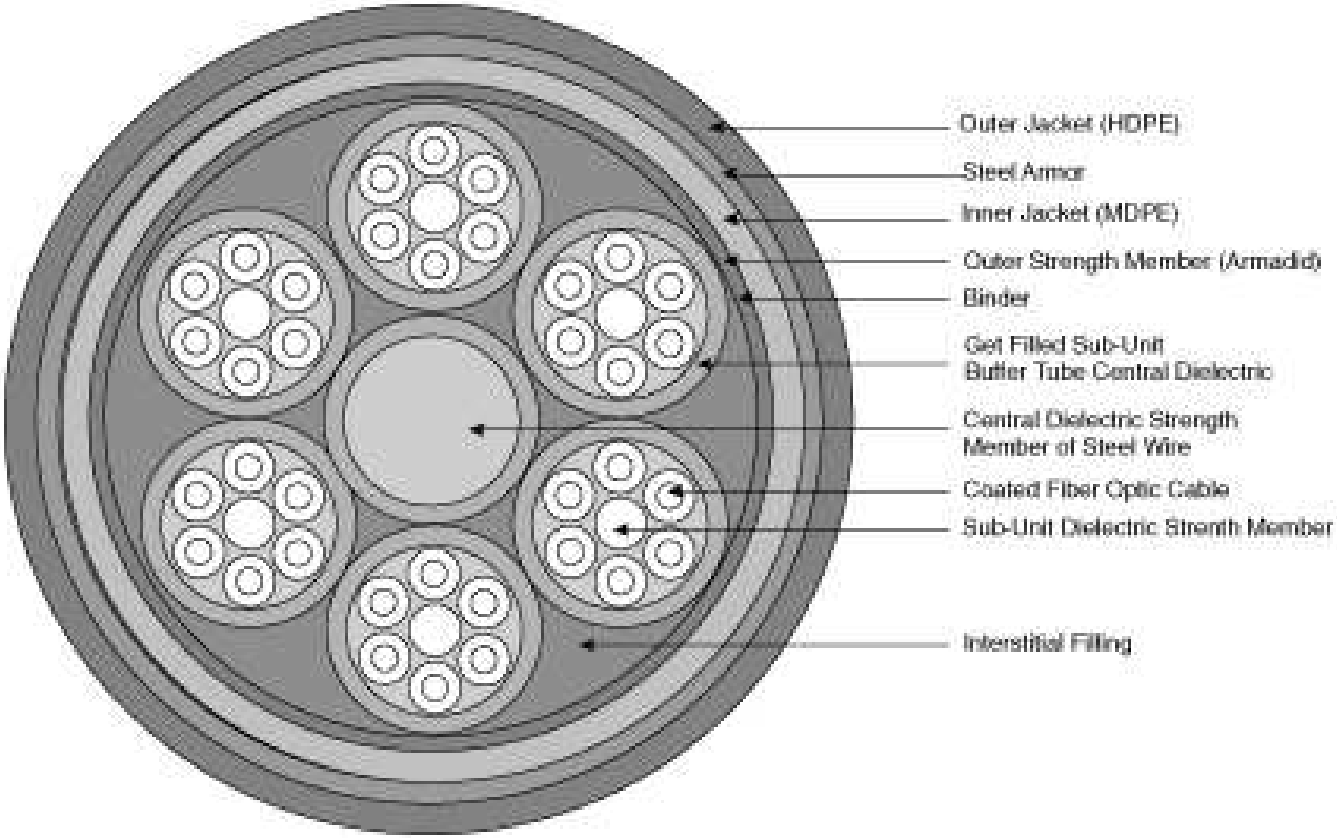
Video: http://www.fabila.com/proyectos/ftth/videos/HIT_fiber_optics.swf or

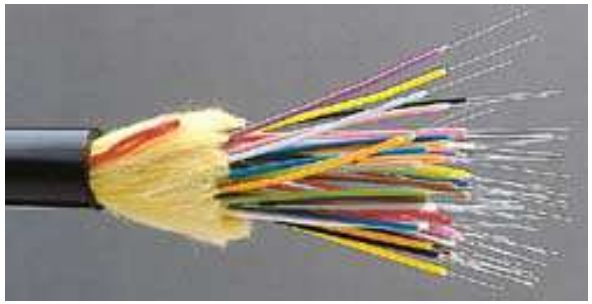
HIT_fiber_optics.wmv

Wavelength ranges

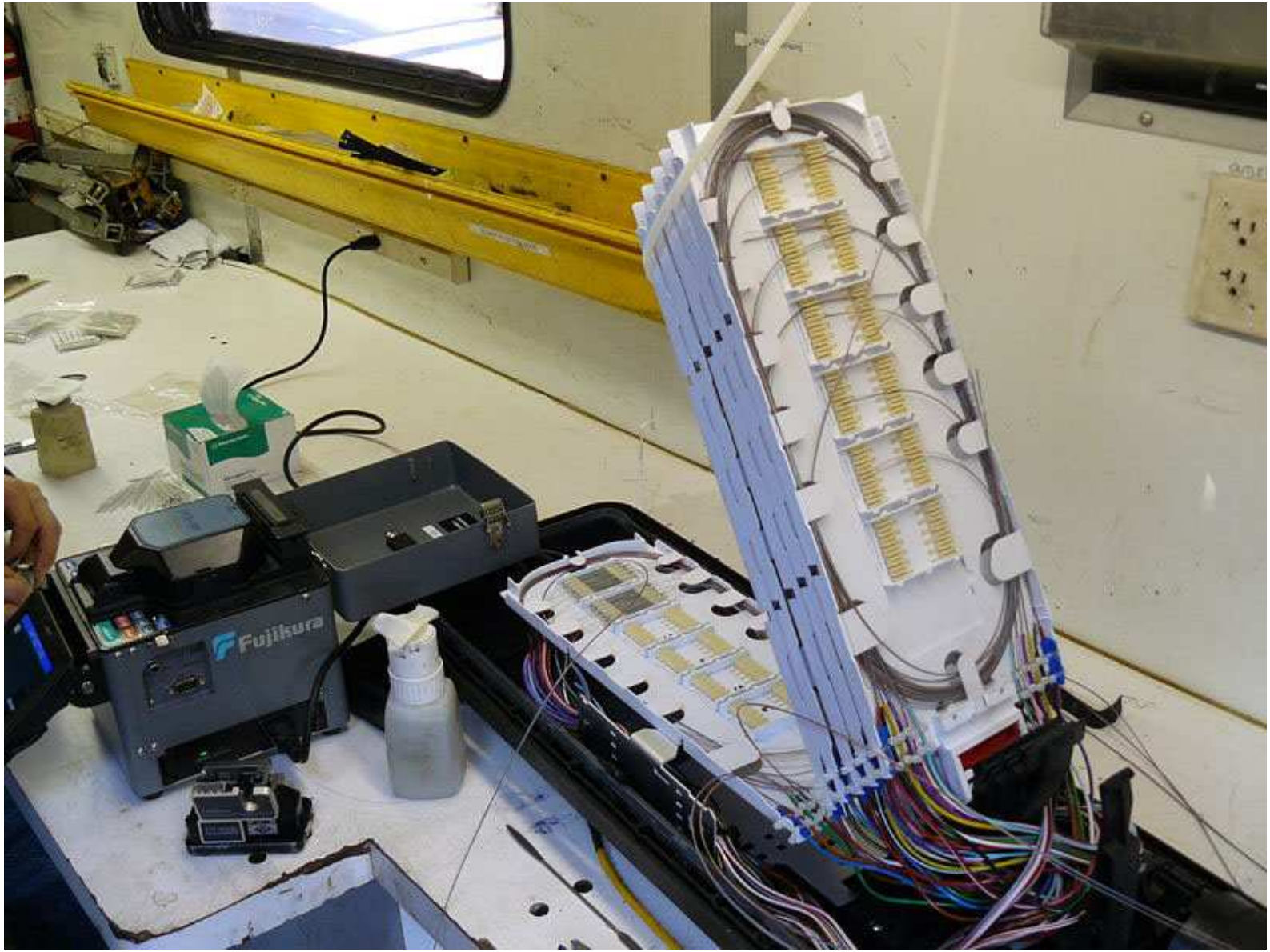


Fiber optic cables

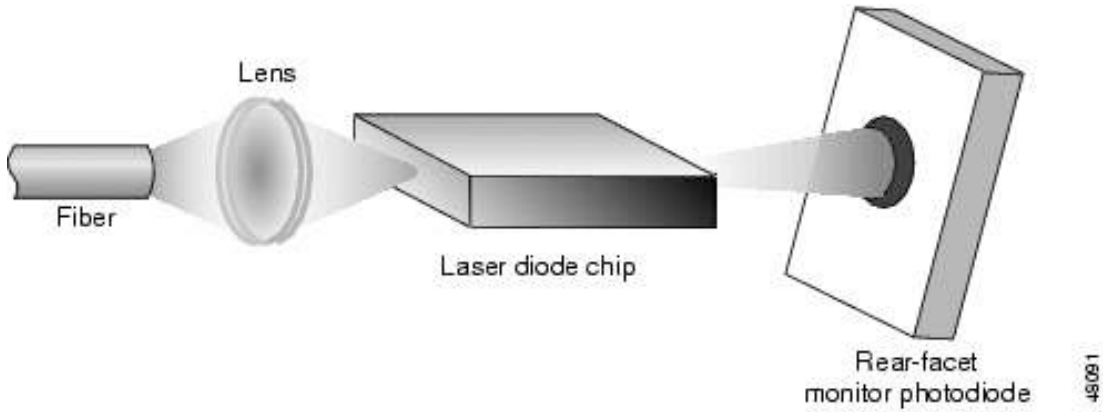




Splicing fibers

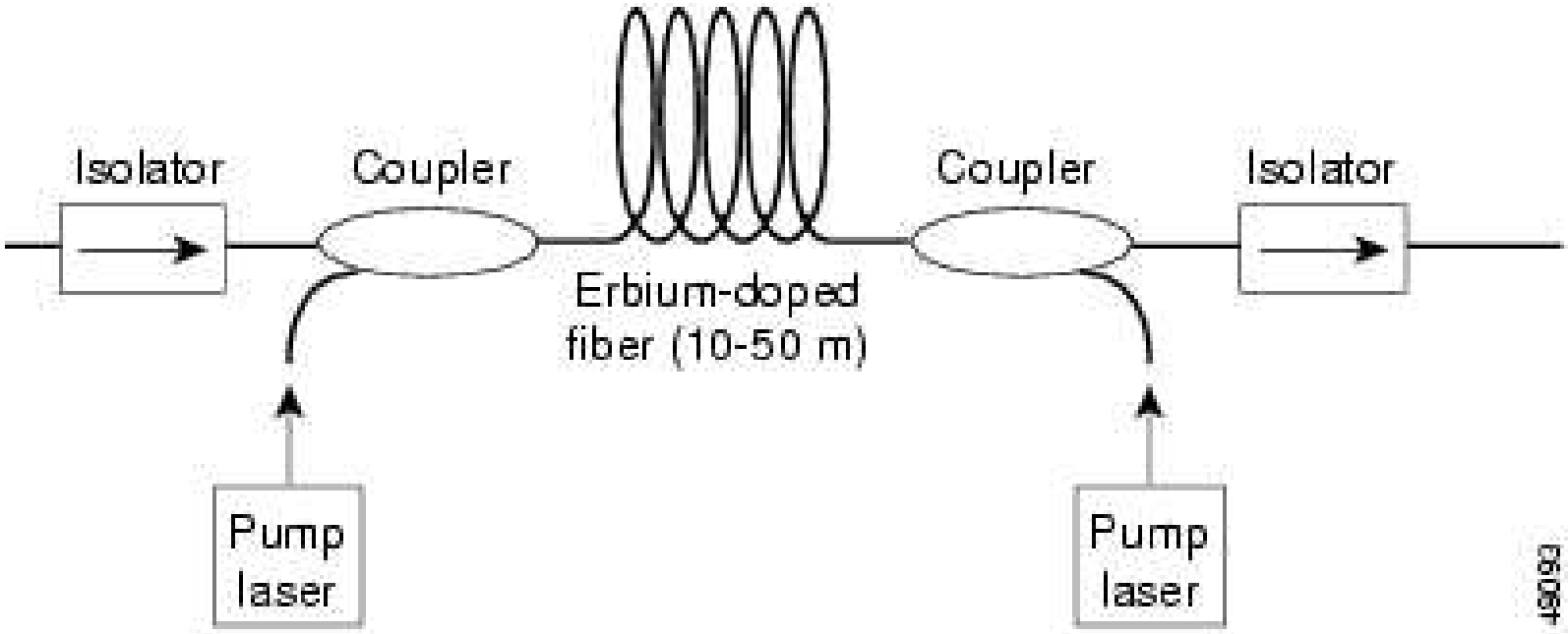


Generating the signal



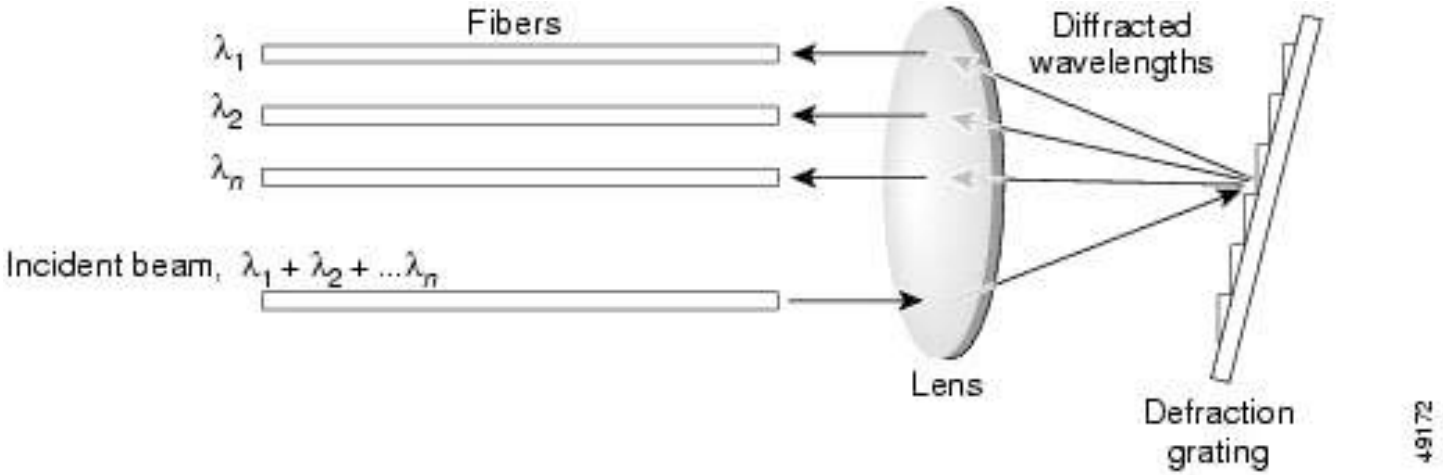
Amplification

Erbium-doped fiber amplifiers



Extracting the signal

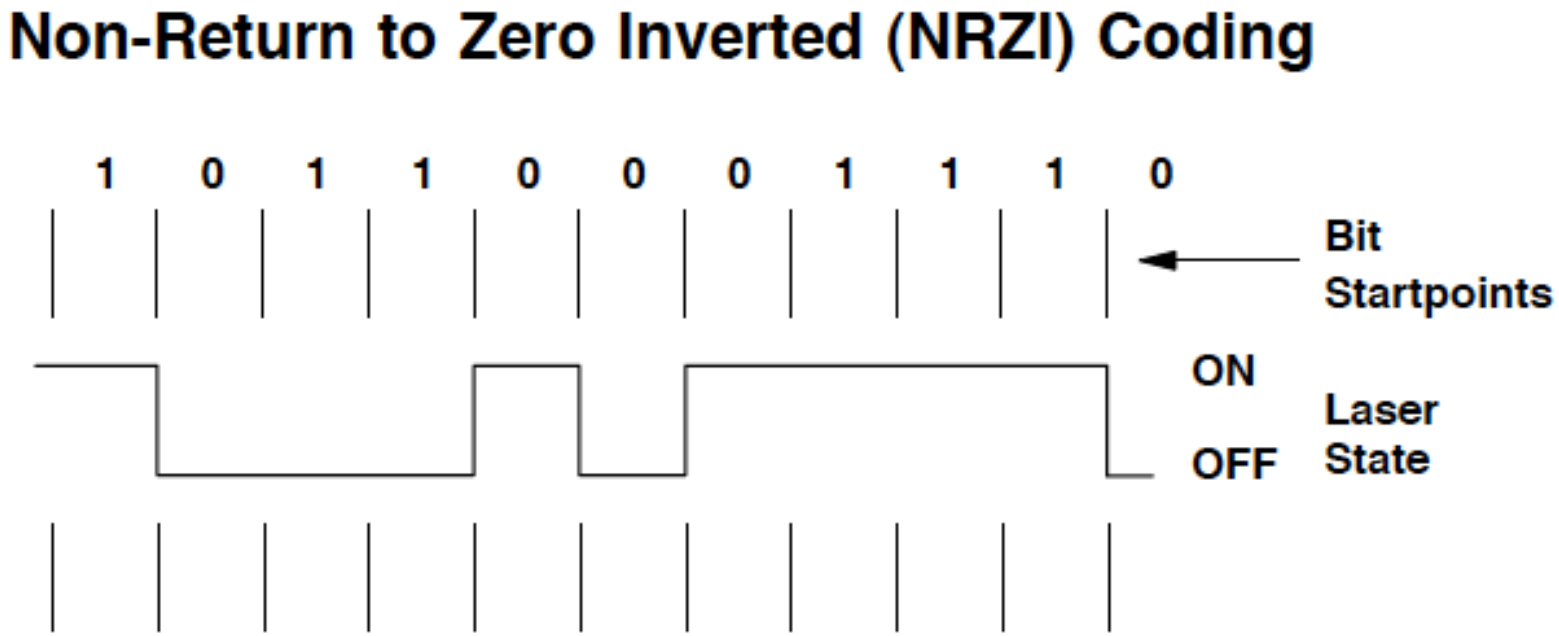
DWDM: dense wavelength division multiplexing



Up to 256 separate bands can be transmitted on one cable!

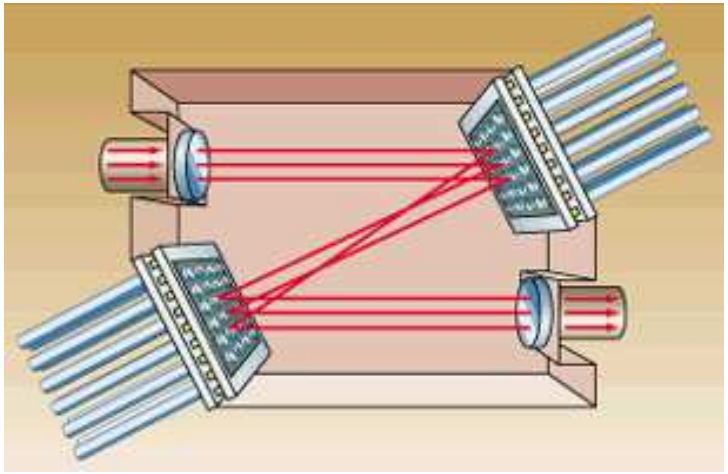
Encoding

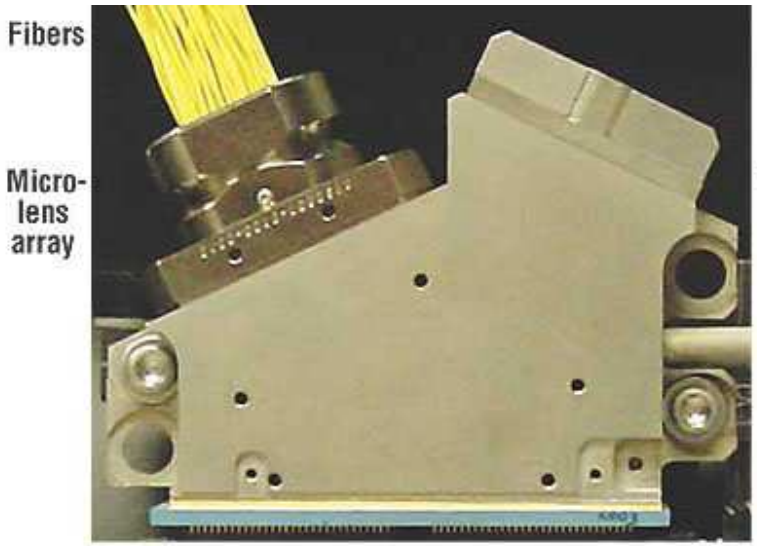
Non-return to zero inverted (NRZI) coding:



Requires a loosely-specified “clock” speed. Running on “idle” involves steady square wave at that clock speed.

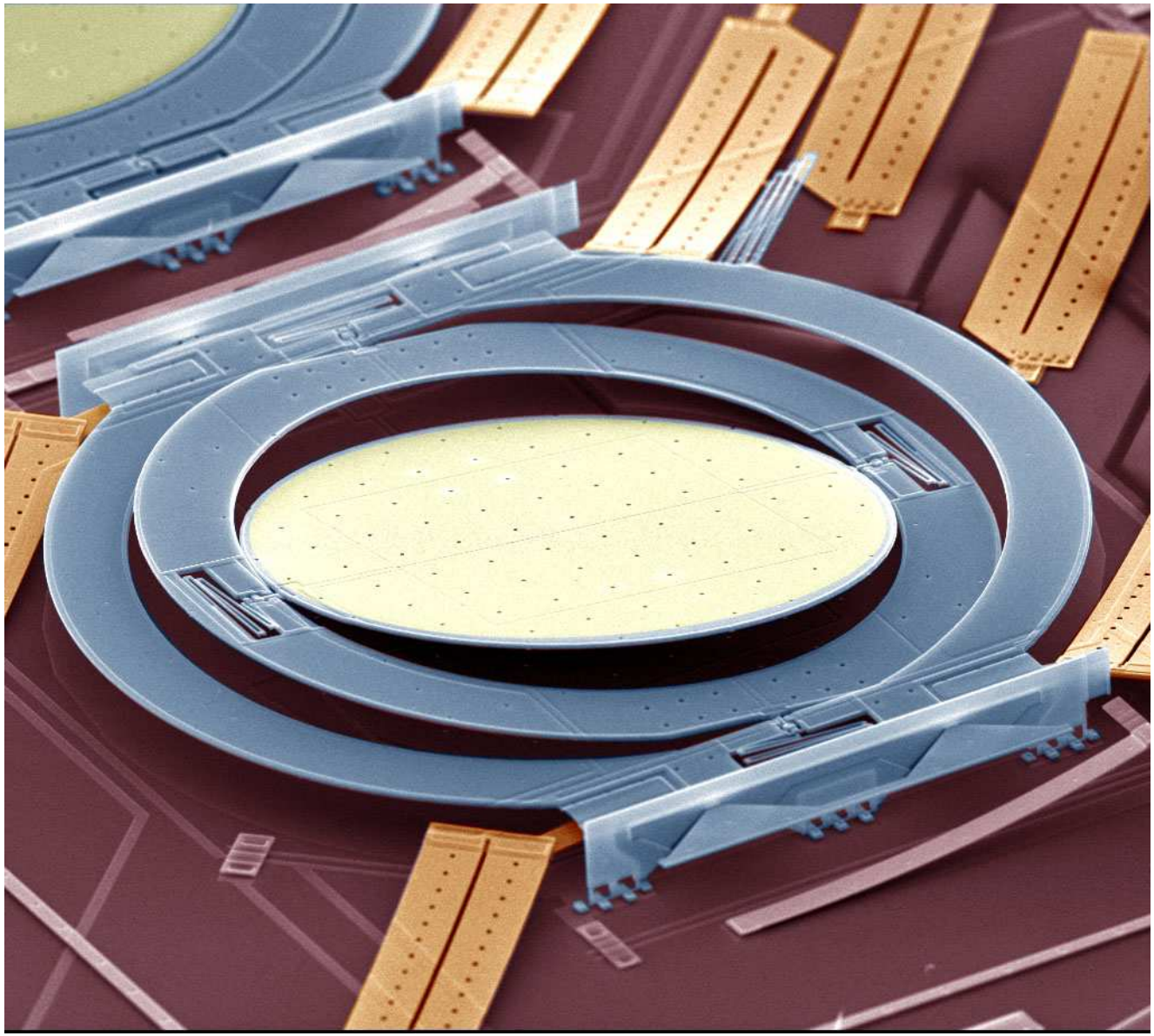
Signal switching



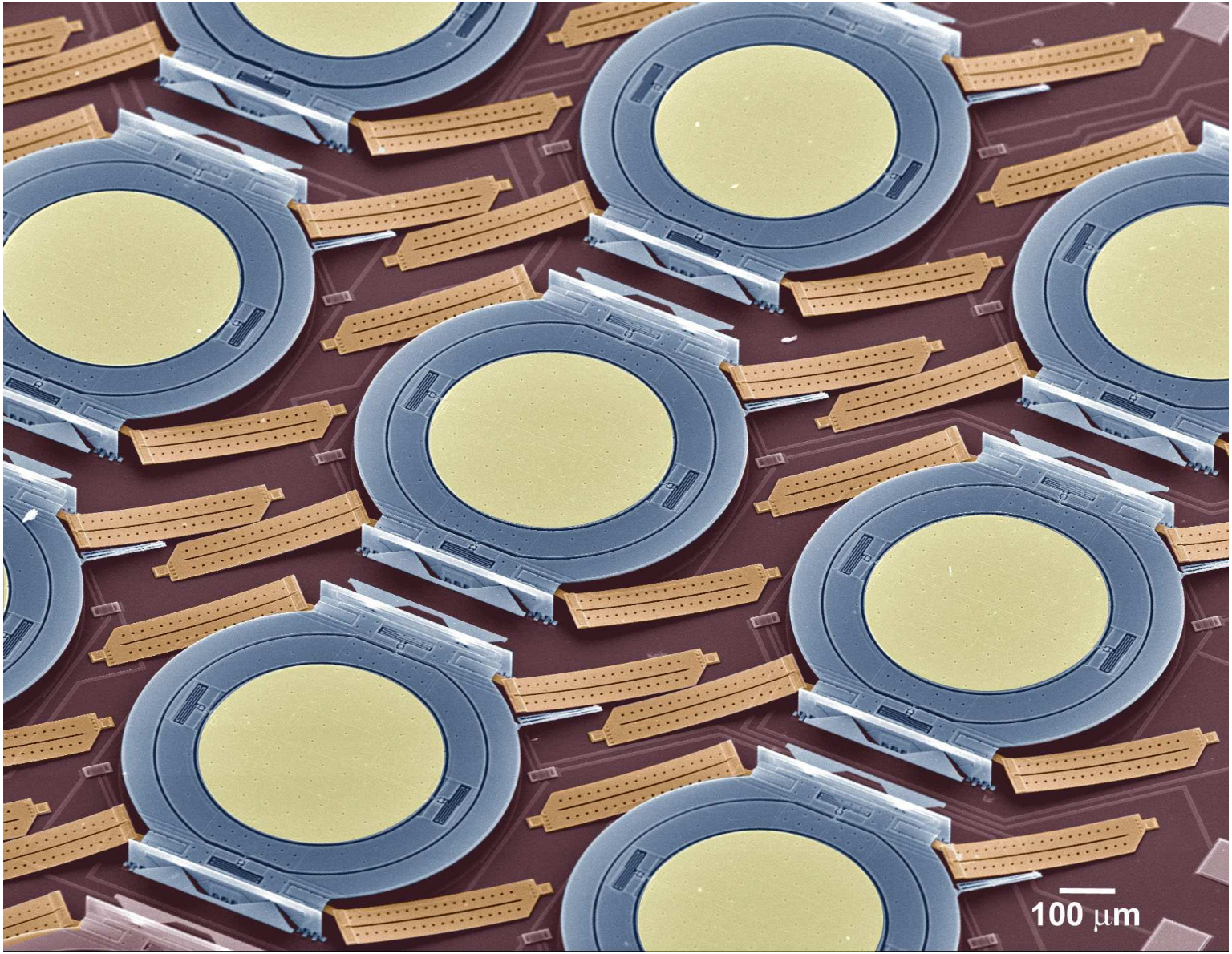


MEMS mirror array

Lucent lambda router



Lucent lambda router II



How much bandwidth do we need?

- NTT record (2006): 14 000 Gbit/s (14 Tbps) was done with 140 wavelengths, with each wavelength operating at 111 Gbps.
- Long Island households: Suffolk 470,000; Nassau 448,000.
- One phone call: 4 kHz bandwidth, 128 levels gives 0.5 Mpbs.
- One simultaneous phone call per household: 10^6 households, 0.5 Mbps: 4% of bandwidth of one optical fiber.
- One HDTV video feed: $1920 \times 1080 \times 60$ pixels per second, with 3×256 grey levels per pixel, gives 96 Gbps.
  - However, mildly lossy compression helps a lot! 10–100$\times$ bit rate reduction.
- 1000 video channels: 1 Gbps$\cdot$1000=1 Tbps. Not breaking a sweat on a single 14 Tbps fiber.
- Video on demand to every Long Island household with 100:1 video compression: 10^6 households, 1 Gbps per household, or 10^3 Tbps, or 70 optical fibers.

DLP projectors

Video: http://www.dlp.com/includes/demo_flash.aspx