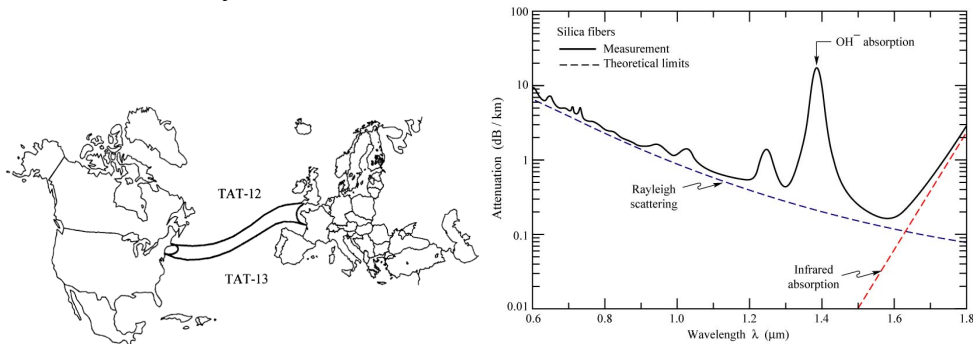
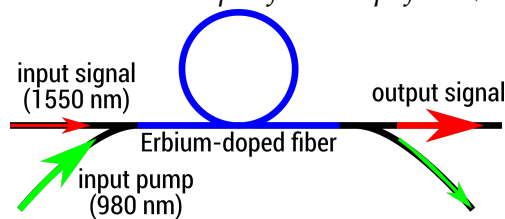


## Around the world

In 1995, the TransAtlantic Telephone (TAT) 12/13 network was deployed to connect the U.S. (Geen Hills & Shirley), the U.K. (Lands End) and France (Penmarc'h).



The segment TAT-13 connecting France to the U.S. is a 6321 km long optical fiber bundle. The signal is a  $\sim 1 \mu\text{W}$  laser with wavelength  $1.55 \mu\text{m}$ , injected in the silica fiber. To compensate for propagation-induced losses (see above), TAT 12/13 was the first trans-Atlantic system to make use of *Erbium-doped fiber amplifiers (EDFA)* as optical repeaters.



An optical repeater is a device which amplifies the input signal through stimulated emission. EDFAs are short fibers (10 m long,  $2 \mu\text{m}$  radius) where Erbium atoms have been introduced (with a density  $\sim 5 \times 10^{23} \text{ m}^{-3}$ ) and are pumped by a *pump laser* at 980 nm of 50 mW. Erbium atoms can be considered as a three-level system with the following properties :

Quantity	Value
$\tau_{21}$	11 ms
$\lambda_{21}$	1550 nm
$\sigma_{21}$	$4 \times 10^{-25} \text{ m}^2$
$\tau_{32}$	$\sim \mu\text{s}$
$\lambda_{13}$	980 nm
$\sigma_{13}$	$6 \times 10^{-25} \text{ m}^2$

**Question** How many repeaters are needed to ensure the signal transmission over TAT-13? For simplicity, you can assume that the pump power remains almost constant through the EDFA.