Activité temps-fréquence au LAAS

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LAAS-CNRS

~ 750 personnes (*Chercheurs, Enseignants-chercheurs, Doc., Post-doc, ingénieurs, administratifs*)

26 équipes de recherche

8 départements scientifiques :

- **Informatique Critique (IC)**
- **Réseaux et Communications (RC)**
- **Robotique (ROB)**
- **Décision et Optimisation (DO)**
- **Gestion de l'Energie (GE)**
- **Micro et Nano-BioTechnologies (MNBT)**
- **RF et optique, de l'EM aux systèmes (HOPES)**
- **Nano-Ingénierie et Intégration (NII)**

Salle blanche (*1500 m²*)

Plateforme de caractérisation

4 axes stratégiques transverses :

- **Intelligence ambiante**
- **Vivant**
- **Energie**
- **Espace**

Low phase noise microwave sources – classical approaches

100 MHz — 1 GHz — 10 GHz — 100 GHz

Piezoelectric
Quartz
BAW
$Q > 10^6$

Piezoelectric
Quartz
SAW
$Q > 10^4$

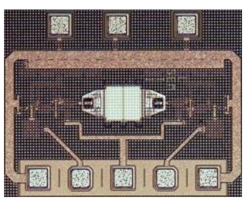
Coaxial
Resonator
$Q \sim 5\ 10^2$

Dielectric
Resonator
$Q_{unloaded} \sim 10^4$

Dielectric
Resonator
$Q_{unloaded} \sim 10^3$??

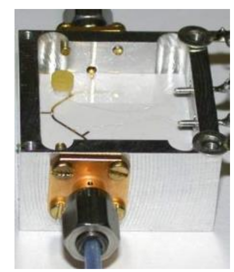
Piezoelectric
Micro-machined
FBAR or SMR
$Q \sim 5\ 10^2$

Sapphire
WGM Resonator
$Q_{unloaded} \sim 10^5$



5 GHz FBAR oscillator
(LAAS – ST Micro)

5 GHz sapphire DRO (LAAS-FEMTO-ST)



16 GHz injection locked DRO
for optical clock distribution (LAAS)

Cryogenic microwave oscillator

100 MHz — 1 GHz — 10 GHz — 100 GHz

Piezoelectric Quartz BAW $Q > 10^6$

Piezoelectric Quartz SAW $Q > 10^4$

Coaxial Resonator $Q \sim 5\ 10^2$

Dielectric Resonator $Q_{unloaded} \sim 10^4$

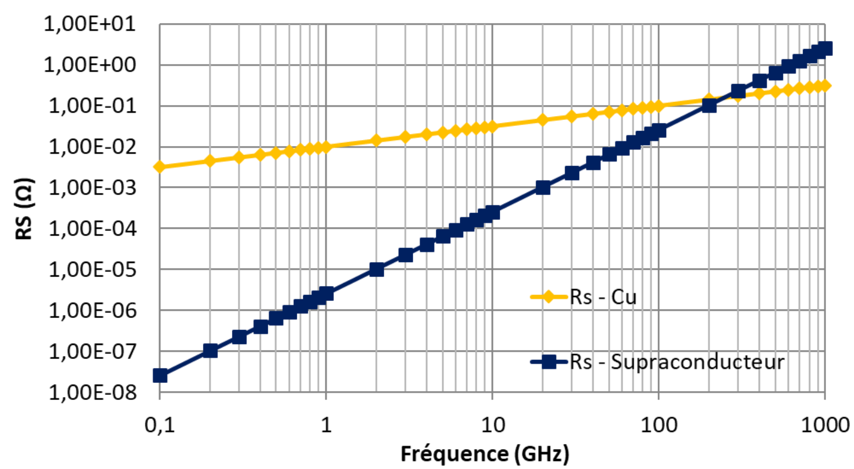
Sapphire $Q_{unloaded} \sim 10^5$

Dielectric Resonator $Q_{unloaded} \sim 10^3$??

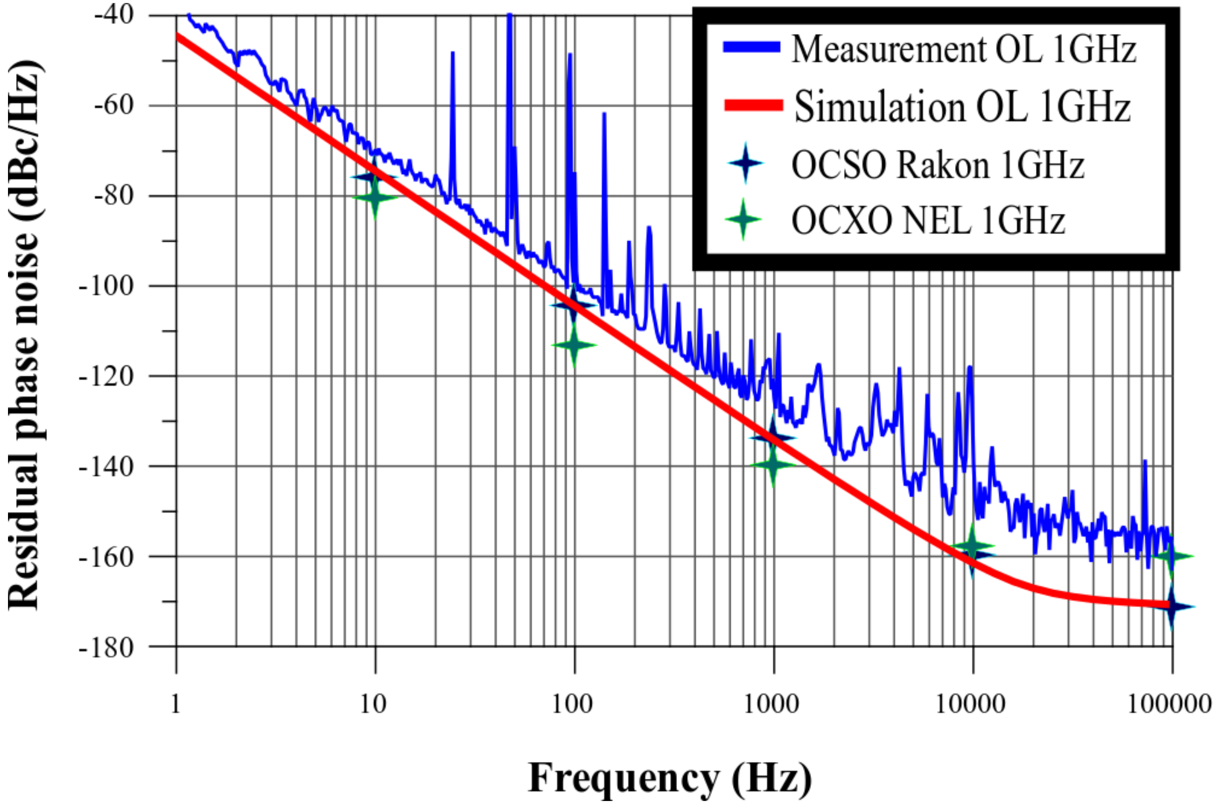
High Tc Superconductor planar resonator

Unloaded Q measured at 1 GHz and 77 K

$Q_0 = 275\ 000$

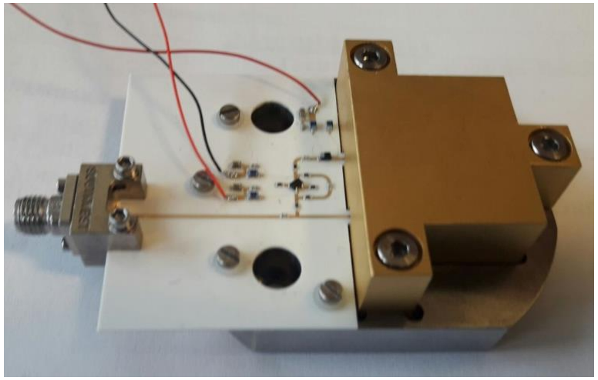


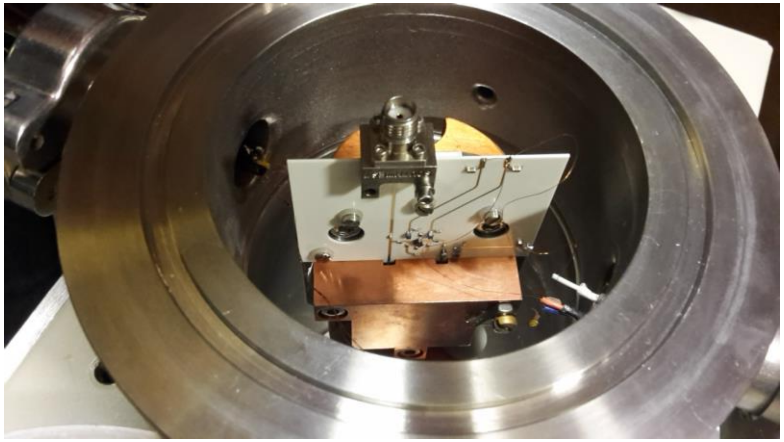
Cryogenic microwave oscillator



David Chaudy et al., IEEE-IFCS 2018

70K





THALES

DGA

Optoelectronic oscillator (OEO)

100 MHz — 1 GHz — 10 GHz — 100 GHz

Piezoelectric Quartz BAW $Q > 10^6$

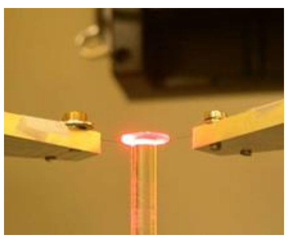
Piezoelectric Quartz SAW $Q > 10^4$

Coaxial Resonator $Q \sim 5\ 10^2$

Dielectric Resonator $Q_{unloaded} \sim 10^4$

Sapphire $Q_{unloaded} \sim 10^5$

Dielectric Resonator $Q_{unloaded} \sim 10^3$??



Optical delay line (4 km)

$Q_{10GHz} = 6\ \ 10^5$

Passive optical resonator ($Q_{opt} = 2\ 10^9$)

$Q_{10GHz} = 10^5$

Passive optical resonator

$Q_{100GHz} \sim 10^6$

Active optical resonator (mode locked laser with 400 m fiber loop)

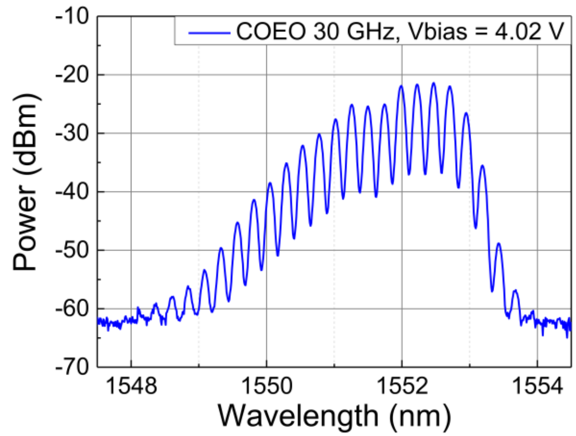
$Q_{30GHz} = 2\ 10^6$

<u>The optical resonator :</u>

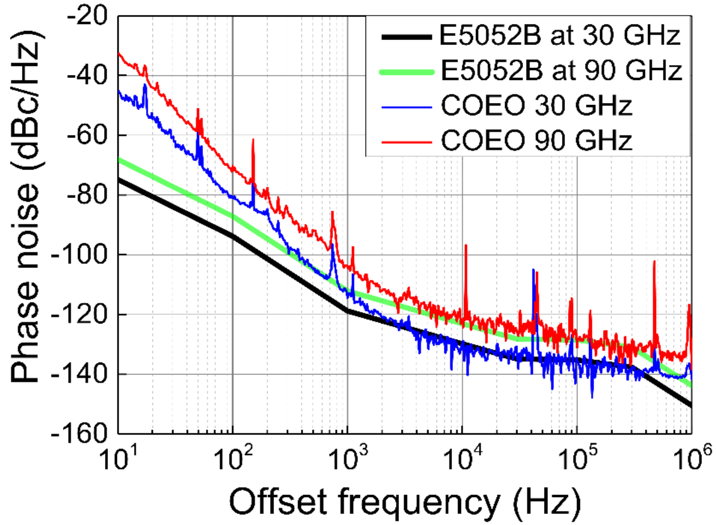
Ultra high Q available

Q ↗ with RF frequency

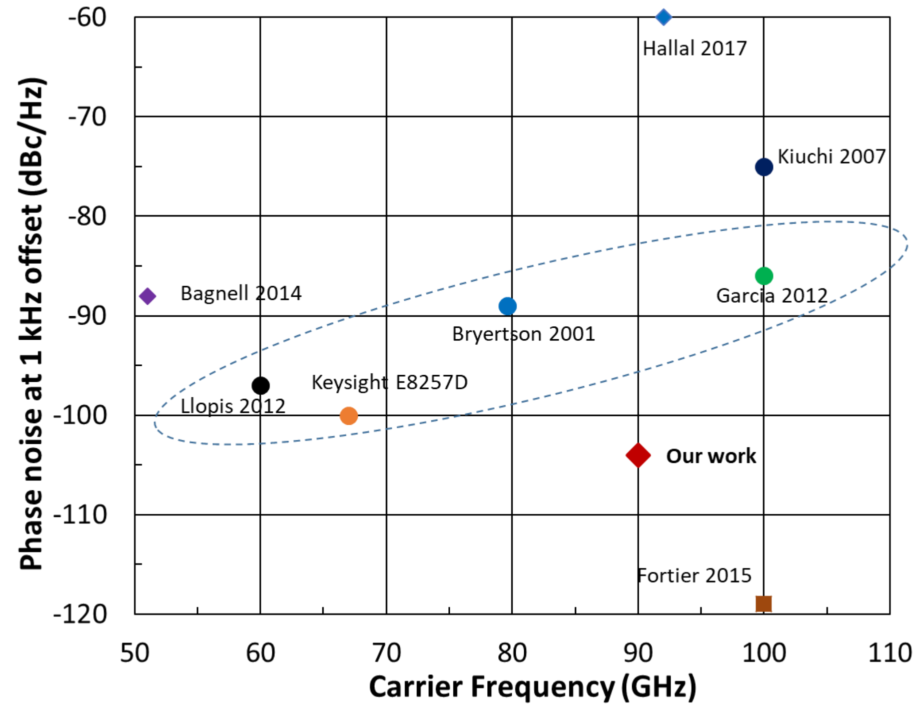
30 GHz and 90 GHz signal generation with a coupled optoelectronic oscillator



Optical comb of the 30 GHz COEO



Phase noise measurements at 30 GHz and 90 GHz



State of the art: comparison with quartz stabilized sources (blue ellipsoid) and other microwave-optics sources – the only better source is the one of NIST (Fortier 2015) which is based on the frequency division of an ultra stable laser source

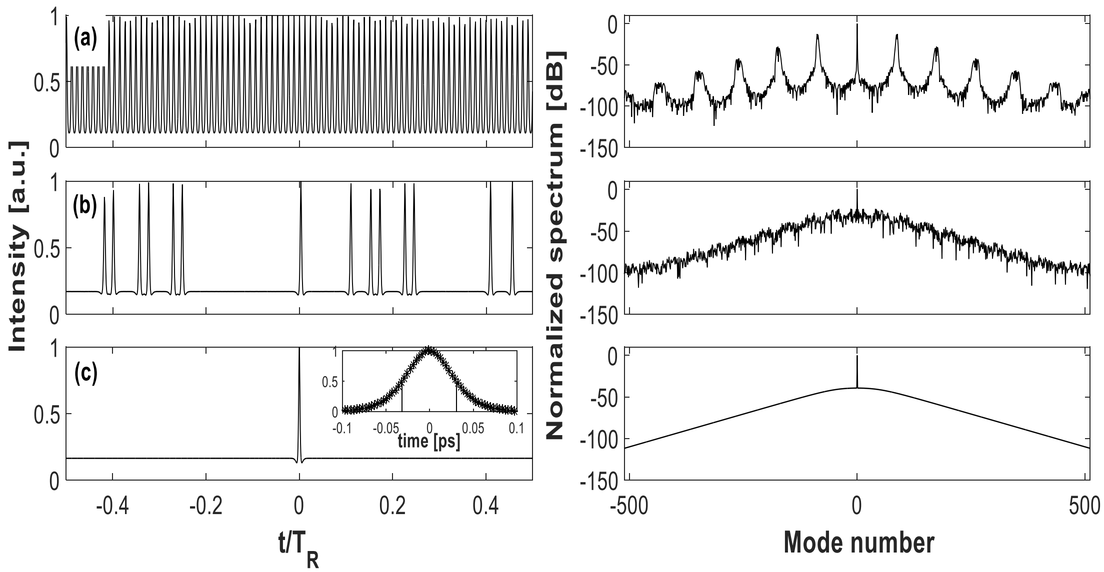
A. Ly, V. Auroux, R. Khayatzadeh, N. Gutierrez, A. Fernandez, O.Llopis, "Highly spectrally pure 90 GHz millimeter-wave synthesis using a 30 GHz coupled optoelectronic oscillator", IEEE Photonics Technology Letters, Vol. 30, Issue 14, July 2018

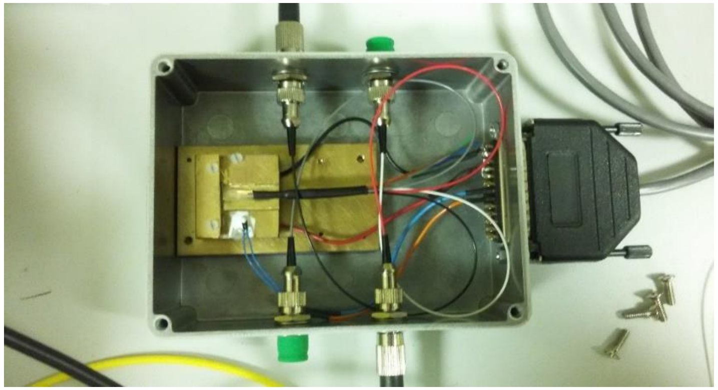
Optical micro-combs

Modeling and characterization of nonlinear Kerr comb generation in an HYDEX micro-ring resonator

FSR = 49 GHz, Q = 2 10^6

N. Gutierrez PhD thesis and CLEO-EQEC, Munich 2017

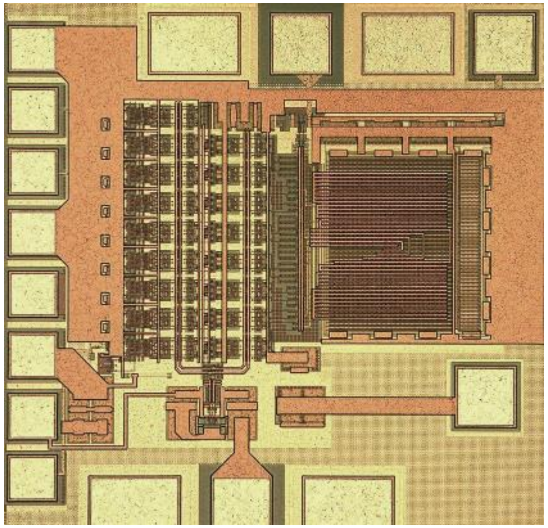




Fully integrated disk resonator technology, vertically coupled to an optical waveguide

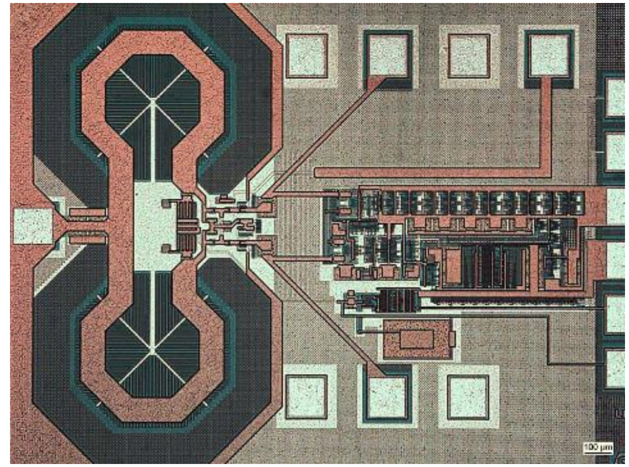
S. Calvez, G. Lafleur, A. Larrue, P.-F. Calmon, A. Arnoult, G. Almuneau and O. Gauthier-Lafaye, “Vertically-coupled microdisk resonators using AlGaAs/AlOx technology”, IEEE Photonics Technology Letters, 27 (9), 982-985 (2015)

Background in frequency synthesis: analog/digital/mixed

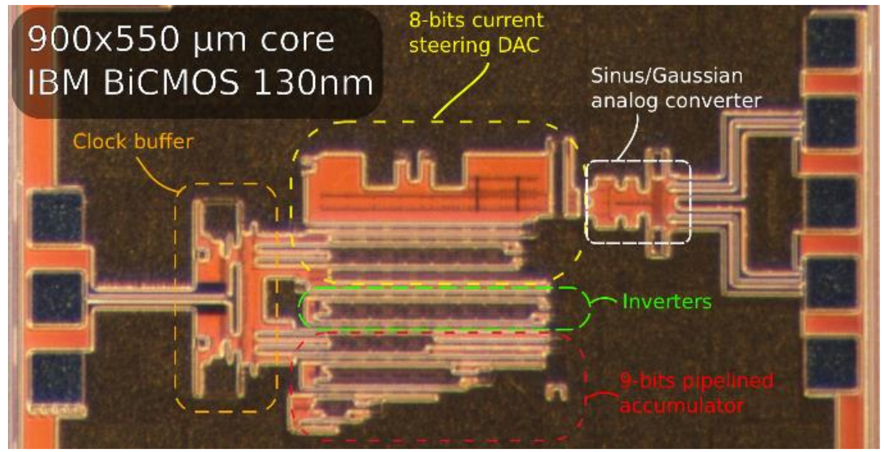


Sine DDS BiCMOS 0,25 µm
6 GHz / 8 bit / 308 mW / 31 dBc SFDR
(2008)

PLL BiCMOS 0,25 µm
10 GHz / 310 mW
(2010)



Sine/gaussian DDS BiCMOS 0,13 µm 16 GHz / 9 bit / 560 mW
SFDR (sine mode) : 46 dBc ; SLRR (gaussian mode) : 43.5 dBc
(2013)



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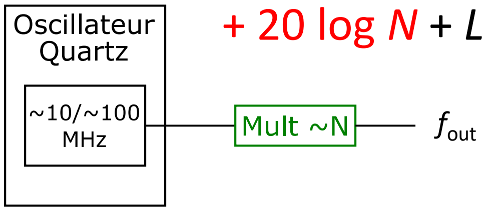
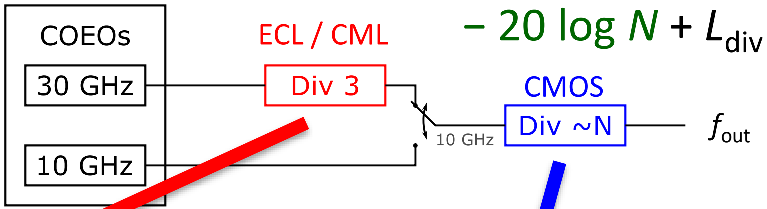
Digital & analog frequency division of microwave signals

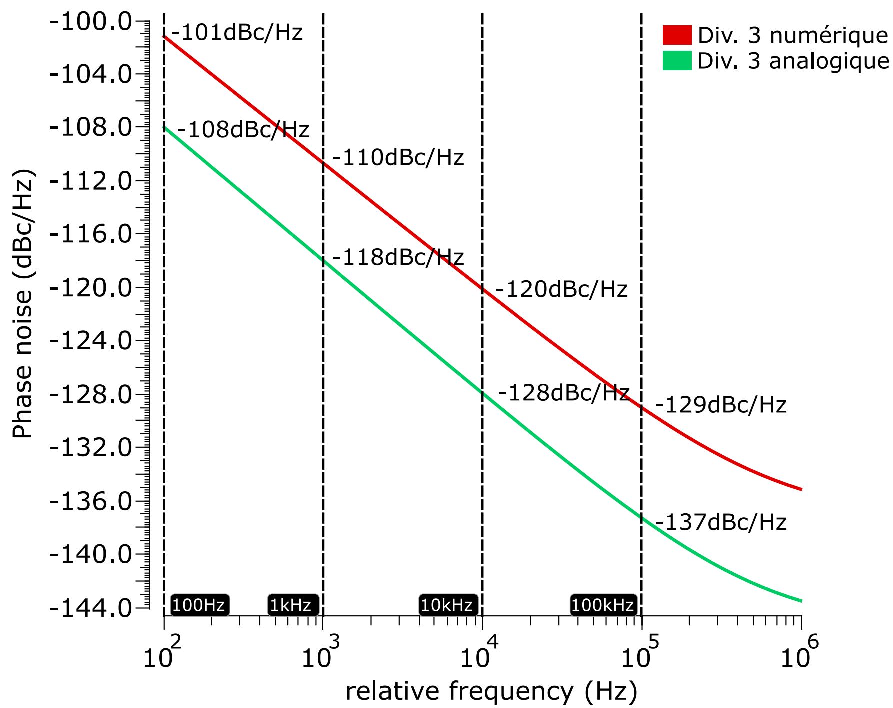
Phase noise:
$+ 20 \log N + L_{mult}$

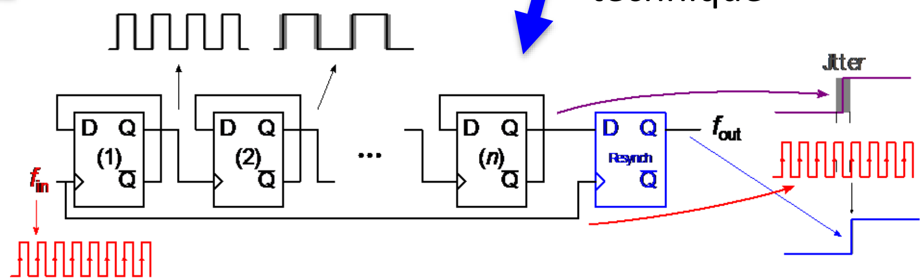


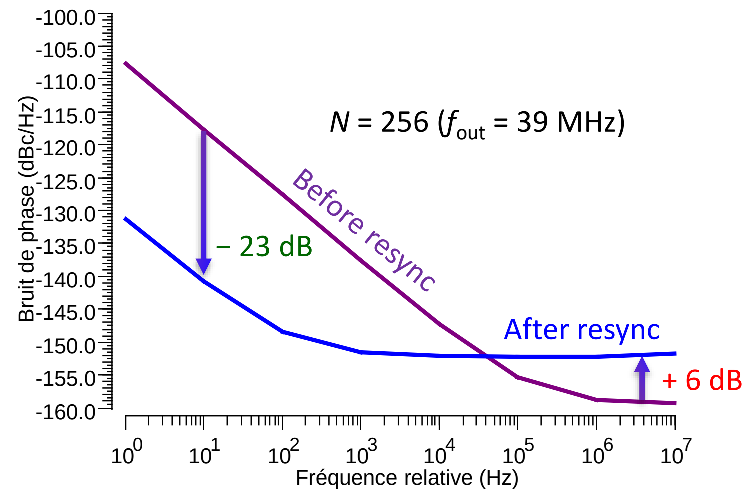
Phase noise:
$- 20 \log N + L_{div}$



Resynchronisation technique







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IEEE-MWP 2018
International Topical Meeting on Microwave Photonics

Toulouse, France, October 22-25, 2018

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