

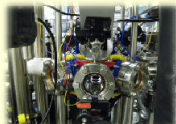
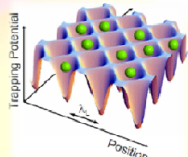
# Frequency metrology at NMIJ and possible collaborations with Europe

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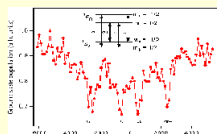
## Frequency metrology at NMIJ

**Yb Optical Lattice Clock:**  
A candidate for the next frequency standard

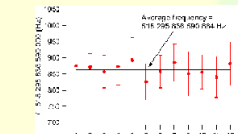


Vacuum chamber for trapping atoms

Ultracold Yb atoms in the MOT



Observed spectrum of the clock transition in  $^{171}\text{Yb}$

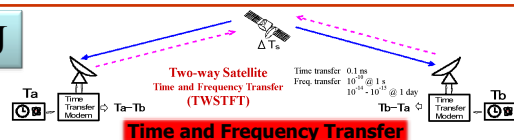


Absolute frequency measurement of the clock transition in  $^{171}\text{Yb}$

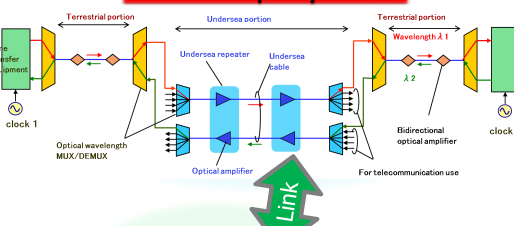
Source of uncertainty	Bias (Hz)	Uncertainty (Hz)
Blackbody radiation	+1.32	0.13
Gravitation	-1.19	0.03
2nd order Zeeman	+0.4	0.05
Scalar light shift	0	14
Clock laser light shift	-0.04	-0.01
Paper lock error	0	23
UTC(NMIJ)	0	5
<b>Total</b>	<b>+0.49</b>	<b>27</b>

Frequency biases and uncertainties in NMIJ Yb optical lattice clock (Very small corrections!)

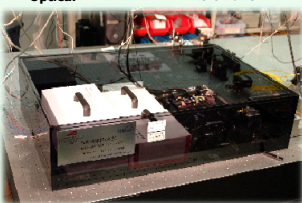
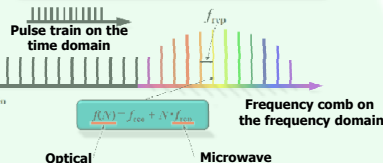
Our value was listed up in the *Mise en pratique* list of recommended radiations to realize meter (C2-2009).



Two-way Satellite Time and Frequency Transfer (TWSTFT)



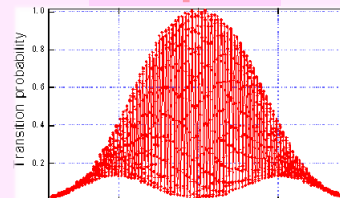
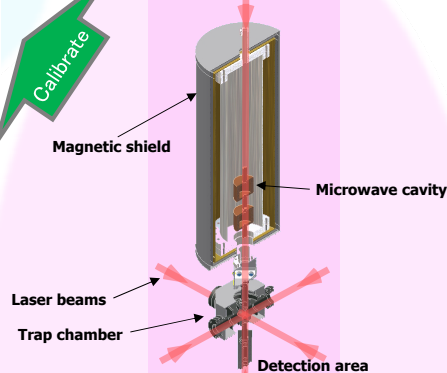
Optical Frequency Comb: Frequency linker between optical and microwave



Japanese National Standard of "Length"

Length metrology

**Cs fountain:**  
Primary frequency standard



Ramsey fringe of NMIJ-F1

Source of uncertainty	Bias	Uncertainty
2nd order Zeeman	185	0.5
Black body radiation	-17.8	1.4
Gravitation	1.6	0.1
Cold collisions	0.0	3.3
Distributed Cavity Phase	0.0	1.2
Microwave power dependence	0.0	0.7
<b>Total</b>	<b>168.8</b>	<b>3.9</b>

Frequency biases and uncertainties in NMIJ-F1 (typical)

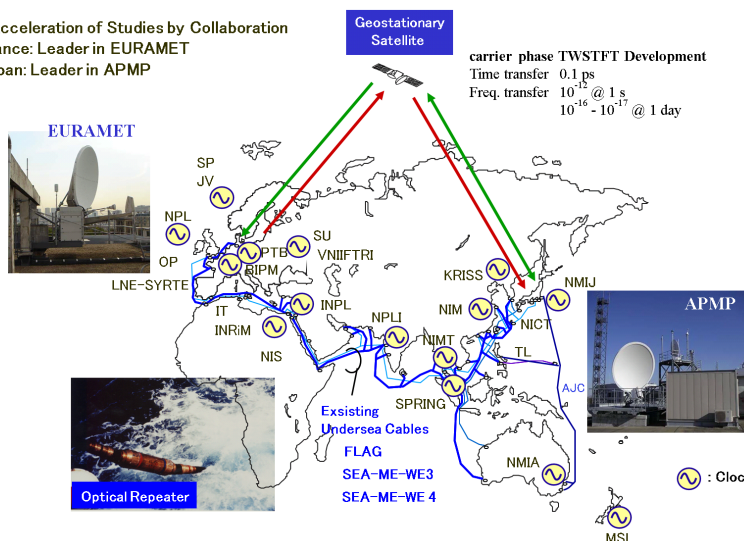
## Establishment of a global scheme is required to accelerate collaboration between EURAMET and APMP in the frame of the Metre Convention.

### Possible collaboration with Europe (1)

#### Construction of time and frequency transfer system between Europe and Japan

◆ Global T&F Transfer by Satellites and Undersea Cables

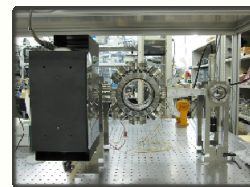
◆ Acceleration of Studies by Collaboration  
France: Leader in EURAMET  
Japan: Leader in APMP



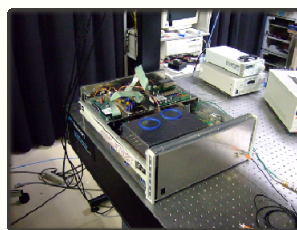
carrier phase TWSTFT Development  
Time transfer  $0.1 \text{ ps}$   
Freq. transfer  $10^{-12}$  @  $1 \text{ s}$   
 $10^{-16} - 10^{-17}$  @  $1 \text{ day}$

### Possible collaboration with Europe (2)

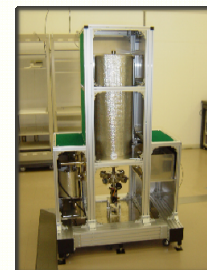
#### International comparison using "portable" standards



Portable optical lattice clock  
Intercontinental frequency comparison  
Space clock



Portable optical frequency comb  
Intercontinental comb comparison



Portable fountain  
Intercontinental frequency comparison