SAND2009-2024P

Doppler Electron Interferometry – A Possible Nano-Dynamics Tool

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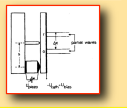
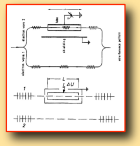
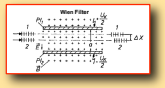
Goal: **Create a Nano-dynamic measurement capability using electron Doppler holography.**

Demonstrated: **1.) Theoretical possibility of single point Doppler measurements with current technology at a signal-to-noise of 25:1.**
2.) Developed a single point electron detector with a 2.5 MHz bandwidth at 6 pA.

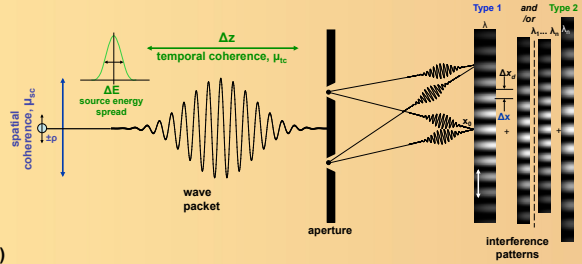
Doppler Electron Dynamic Measurements

	Cause/Effect	Equation	Reference
Velocity		$f_D = \frac{\delta E}{h} = \frac{4\Delta v}{3\lambda}$	Scherzer, Optik 54 (1979)
Electric Field		$\Delta\Phi = \frac{eLU}{\hbar g}$	Schmid, Proceedings (1984)
		$\frac{\partial(\Delta\Phi)}{\partial t} = \frac{eL\,\partial U/\partial t}{\hbar g}$	Möllenstedt, Proceedings (1984)
Magnetic Field	$\Delta\Phi = eLB\Delta x$ 	$\Delta\Phi = -\frac{e}{\hbar}\oint B_n ds$	Möllenstedt, Proceedings (1984)
		$\frac{\partial(\Delta\Phi)}{\partial t} = \frac{e}{\hbar}\Delta\Theta_m$	Chen, Opt. Comm. 110 (1994)
			Voelkl, Intro to Electron Holography

One fringe (2π or λ) = 4.1×10^{-15} Wb (V s)

e electron charge
U voltage applied to tube
Φ phase shift caused by the object
G group velocity
B magnetic field
Θ_m enclosed magnetic flux

Coherence Limitations

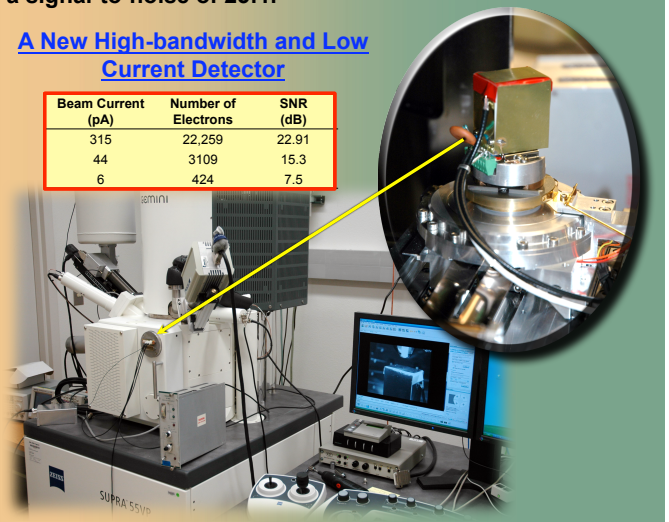


$$I(t) \propto 1 + \left|\mu^{sc}\right|\left|\mu^{tc}\right|\cos\left(2\pi k_0 \beta x_d - 2\pi f_D t\right)$$

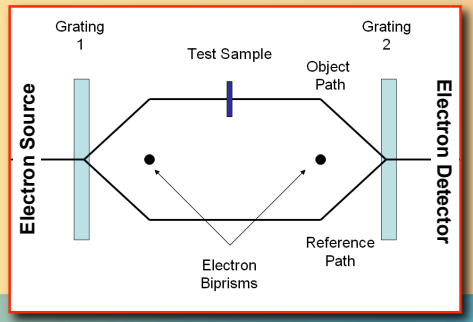
- **Spatial coherence limits beam current to a signal-to-noise ratio of 25:1**
- **Temporal coherence of n<5000 waves poses no problem.**

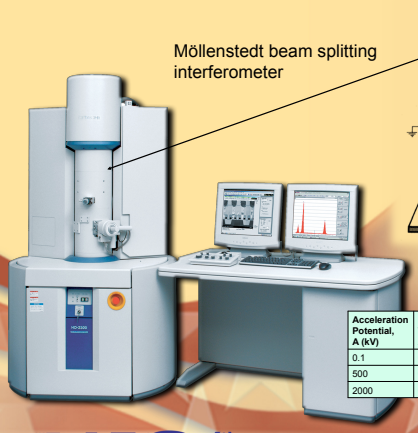
A New High-bandwidth and Low Current Detector

Beam Current (pA)	Number of Electrons	SNR (dB)
315	22,259	22.91
44	3109	15.3
6	424	7.5

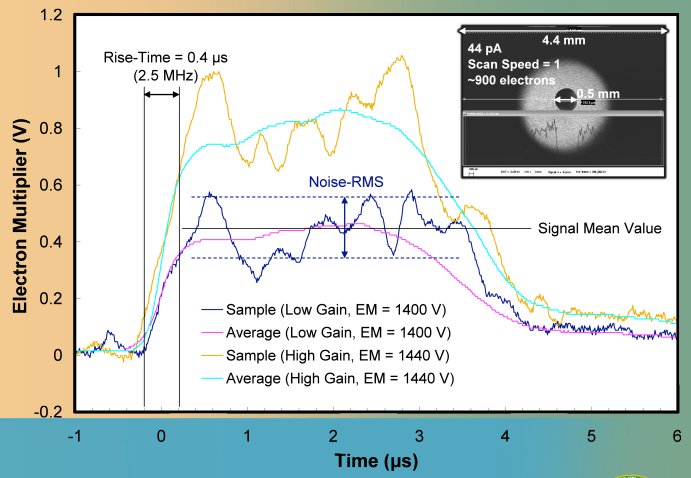


Proposed Mach-Zehnder Interferometer: Increases Useable Beam Current





Acceleration Potential, A (kV)	Wavelength, λ (nm)	Wavenumber, k (1/nm)	v/c
0.1	0.12264	8.154	0.01978
500	0.00142	703.594	0.86286
2000	0.00050	1982.858	0.97907



National Nuclear Security Administration

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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