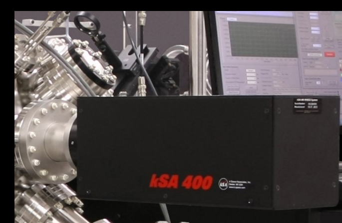
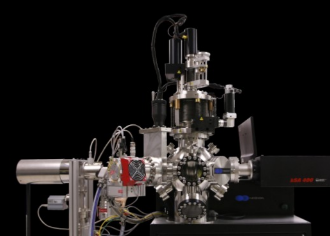
High-pressure RHEED System





Features:

- Layer-by-layer, 2D growth control.
- Deposition of unit cell thick films with excellent thickness control via RHEED intensity oscillations.
- Deposition of epitaxial films, multilayer heterostructures with exceptional interface control.
- Oxygen compatibility up to 500mTorr (differentially pumped).

The essential components of a high-pressure RHEED system are (1) RHEED electron gun and RHEED screen, (2) double differential pumping system and accessories for high-pressure operation and (3) a high-sensitivity CCD camera for image processing and (4) data acquisition software for analysis.

High-pressure RHEED systems are routinely integrated with Neocera PLD systems, but can also be integrated with existing PLD systems. It is however mandatory, that the deposition system should have ports for both the RHEED gun and the RHEED screen at an optimal position with respect to the substrate surface. Care is also required for providing customer-safety from harmful X-rays generated during operation.

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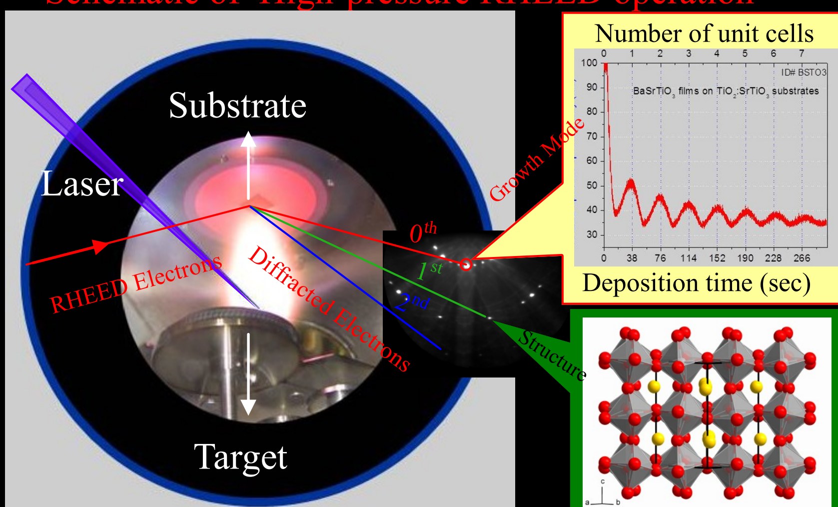
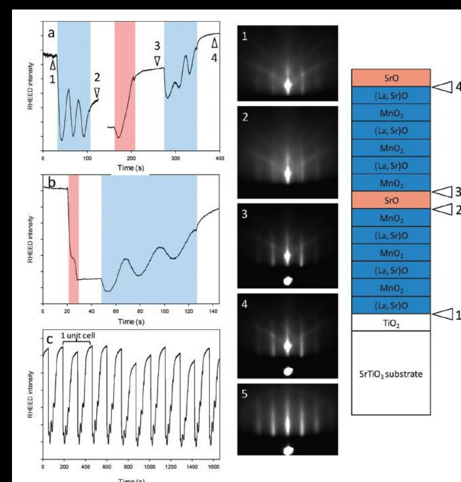
High-pressure RHEED System

In Reflection High-Energy Electron Diffraction (RHEED,) a high energy (20-30 keV) electron beam is incident on the film growth surface at a glancing angle of ~2˚-5˚. The diffraction pattern created on a screen contains information about the crystal structure of the film, stress at the interface, possible impurity phases etc and can be used for real-time monitoring of the film quality. The RHEED oscillations, where the RHEED specular spot intensity is monitored as a function of deposition time provides information on the deposition rate as well as information on the growth mode (2D vs 3D) of the deposited film. A high quality 2D layer-by-layer growth mode is inferred by the observed RHEED intensity oscillations extending to several cycles. Double differential pumping of the RHEED source facilitates high-pressure operation up to about 500mTorr, facilitating real-time monitoring at high oxygen pressures.

Schematic of High-pressure RHEED operation





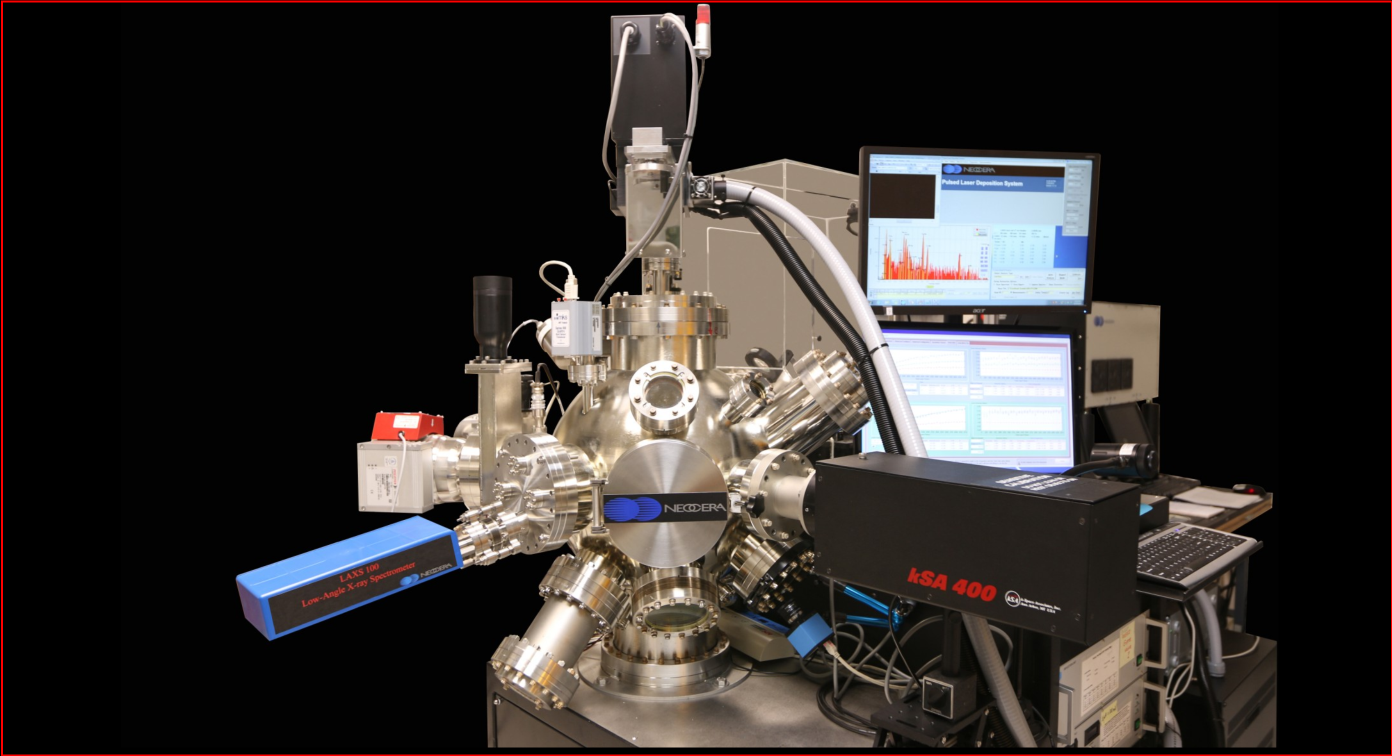
R. G. Palgrave et al., J. Am. Chem. Soc (2012) 134, 7700-7714. (Pioneer 180 Laser MBE /PLD System)

Specifications:

	Feature	Details
1.	RHEED gun	• 1-30KeV • Maximum Beam current: 100micro amps; Stability: Better than 2 x 10^{-4}/hr; Minimum spot size: 40 microns at a distance of 150mm. • Double differentially pumped, max. operating pressure: 500mTorr. • 2 sets of low-aberration magnetic coils for incident and azimuth angle adjustments. • Total angular deflection: +/- 7.5 degrees. • RHEED screen with shutter.
2.	Differential pumps	• 2 sets of turbo pumps backed by fore pumps; Wide range vacuum gauge. • Gate valve to isolate the RHEED gun from the PLD chamber. • Special frame to support the pumps attached to the RHEED gun.
3.	CCD Camera	• Digital high-resolution, Peltier cooled high sensitivity12 bit CCD camera. • Optimized optics for RHEED imaging, allowing for zoom in and zoom out
4.	Data Acquisition Software	• A complete set of software suite for image acquisition and archiving, image analysis and growth rate analysis via RHEED intensity oscillations. • Growth rate acquisition mode allows acquiring intensity data. • Multi-threaded video; Real-time exposure control and back-ground subtraction.

For further information, please contact: sales@neocera.com or +1-301-210-1010, ext 104

Low-Angle X-ray Spectroscopy (LAXS) - *Insitu* Real time Composition Analysis



- Real-time Composition measurement by *in situ* X ray Spectroscopy.
- Simultaneous Structure (RHEED) and Composition (LAXS) measurements.
- Designed Specially for Materials Researchers.
- Ideal for Epitaxial Multi-component Metal-oxide Films.
- Integration with Neocera PLD /Laser MBE Systems - Turn-key solutions.
- Technique can be extended to all Physical Vapor Deposition methods.

- *Silicon Drift Detector.*
- *Energy range of X-rays: 1-20KeV; Energy Resolution 130 eV.*
- *Maximum count rate: 10,000 cps.*
- *3-axis in situ mechanical alignment.*
- *Integrated with PLD and RHEED control software.*

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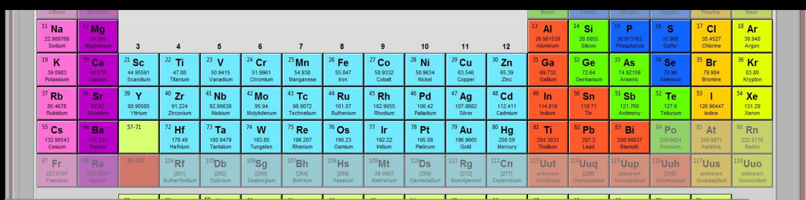
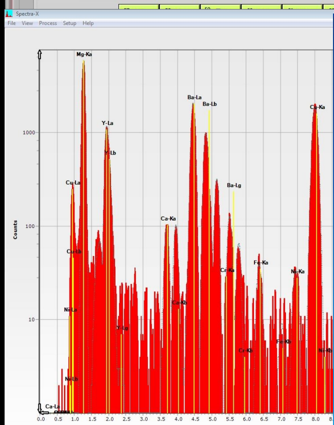
Low-Angle X-ray Spectroscopy (LAXS)

Composition of a thin film is an important materials property that controls the application potential via the underlying electronic structure. Neocera's LAXS uses an X-ray spectroscopic technique developed specifically to access the elemental composition of a multi-component thin film *in-situ*, during film growth (real time). LAXS analyzes X-ray emission spectra of the film excited by an energetic RHEED electron beam typically used in PLD/ Laser MBE Systems. Using a unique methodology of *dynamic spectroscopy,* LAXS automatically acquires, processes, and analyzes multiple spectra as the film is deposited layer by layer. LAXS software communicates seamlessly with PLD system, pulsed laser and process controls, resulting in a fully integrated turn-key PLD-RHEED-LAXS System. The System enables the PLD user, to unravel the relation between the deposition parameter space and the variations in the resulting film composition, and to optimize the process for obtaining a high quality functional multi-component film for a variety of applications.





LAXS takes advantage of intrinsically low incident angles of the electron beam, and small X-ray take-off angles. The low incidence angle, specific for RHEED, facilitates an efficient X-ray generation within the thin film under energetic electron impact. The low take-off angle of X-rays allows minimization of background signal. Special collimator optimizes field-of-view of LAXS to deliver maximum signal-to-noise ratio important for ultra-thin films that are only a few nanometers thick.

LAXS incorporates a state-of-the-art X-ray Spectrometer (Silicon Drift Detector). The X-ray detector and digital pulse processing facilitate high resolution in energy and fast counting rate. LAXS assembly, mounted on a standard vacuum flange, features a 3- axes mechanical stage to align the field-of-view of the instrument precisely to the substrate area irradiated with RHEED electron beam.

Data acquisition software is highly customized and incorporated in LAXS. Spectra processing-program can handle up to 40 elements. User specifies several film elements of interest (PLD target elements for example), and LAXS follows the dynamics of their spectral intensities over the entire deposition process. Complete LAXS user-guide, and a detailed procedure of the System relative sensitivity calibration protocol is provided.

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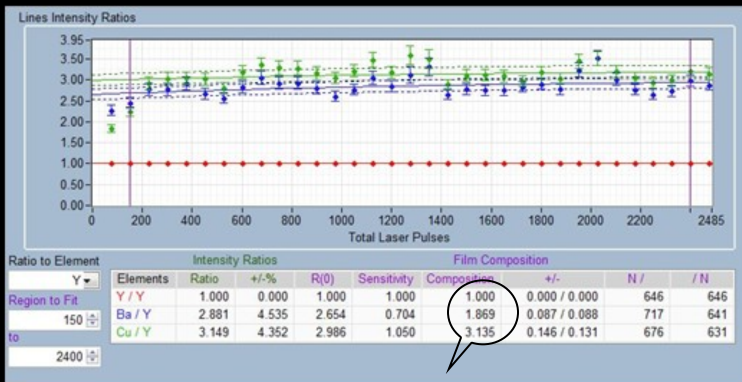
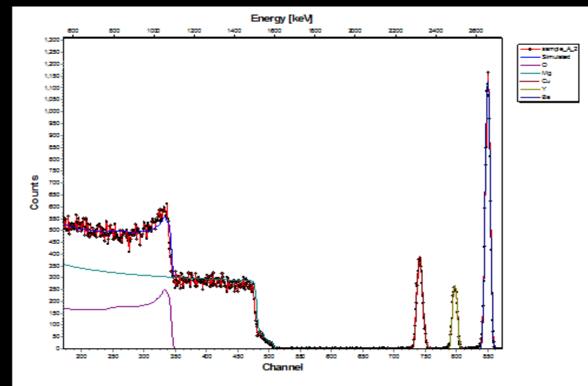
Materials Data: LAXS (on the left) vs RBS (on the right)

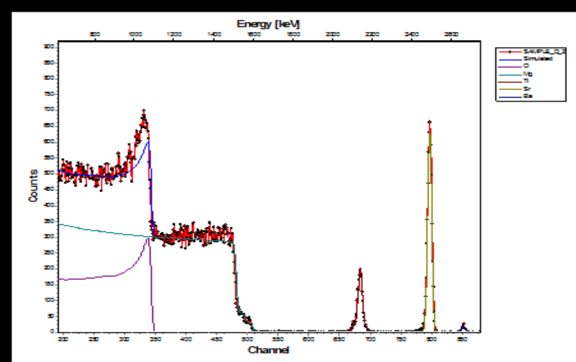


Composition by LAXS: $Y_1Ba_{1.87}Cu_{3.13}O_x$



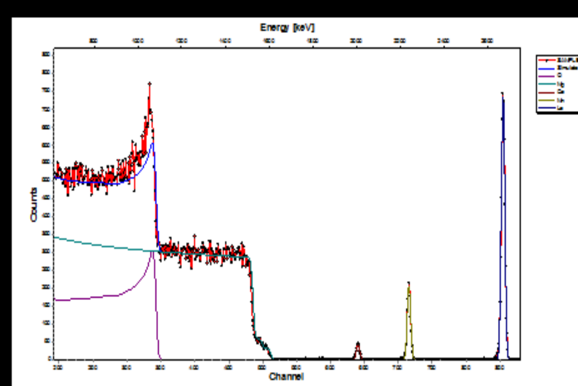
Composition by RBS: $Y_1Ba_{2.06}Cu_{3.1}O_x$

Composition by LAXS: $Sr_{0.97}Ti_1O_x$



Composition by RBS: $Sr_{0.96}Ti_1O_x$

Composition by LAXS: $La_{0.678}Ca_{0.32}MnO_x$



Composition by RBS: $La_{0.67}Ca_{0.32}MnO_x$

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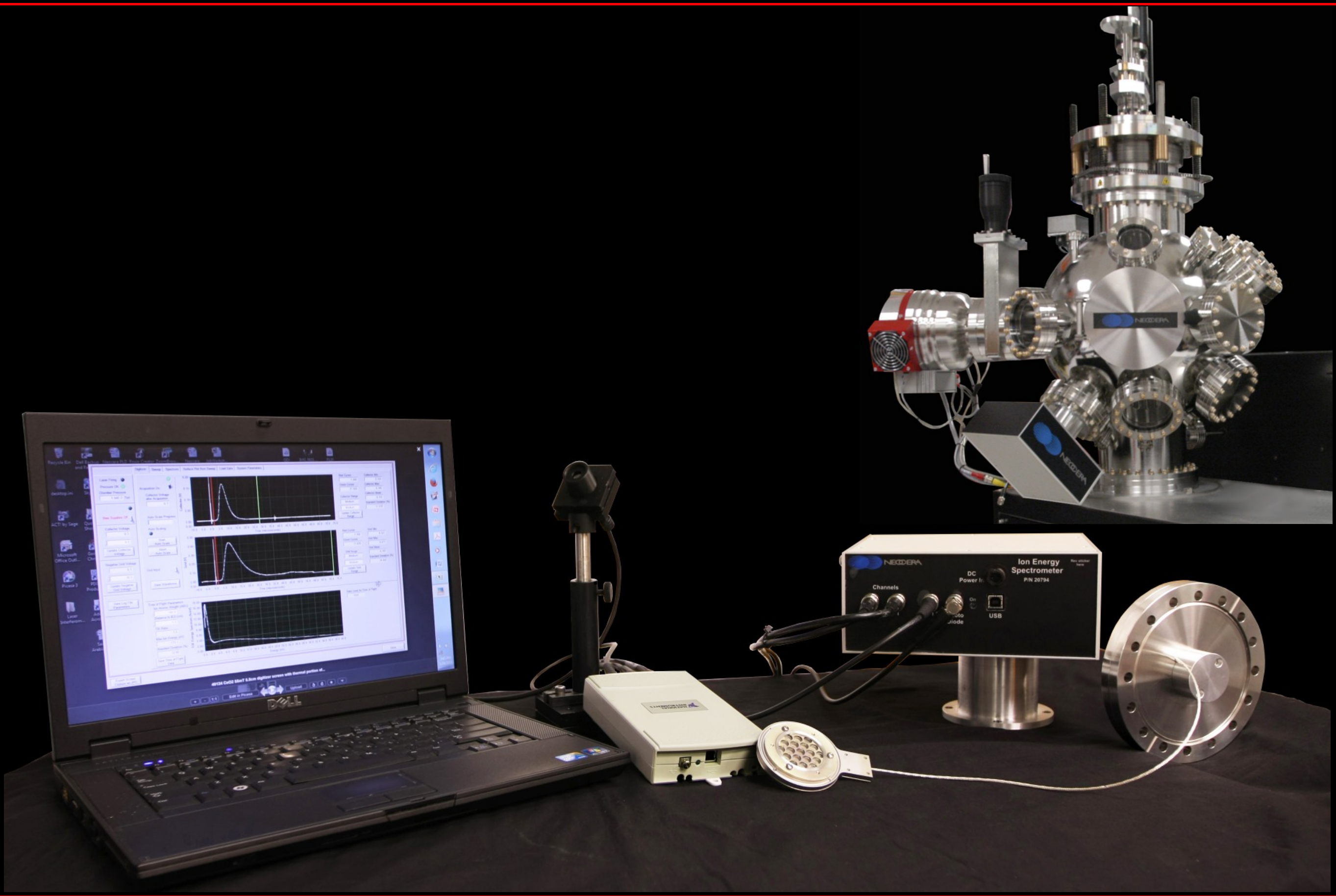
Ion Energy Spectrometer IES-200



Neocera Ion Energy Spectrometer (IES-200) is an Electrostatic Retarding Field-type Spectrometer. Ions of different kinetic energy, arriving at the IES sensor are separated from electrons, discriminated by their energy, and collected by the Spectrometer. The spectrum displayed will provide information on the most important ‘figure-of-merit’ of the PLD deposition process (ie kinetic energy distribution of the ions arriving at the growth substrate).

The spectral distribution function $F(E) \equiv dN(E)/dE$ is the derivative of the measured $N(E)$ where $N(E)$ is the number of ions with energy greater than E. $F(E)$ provides the PLD user quantitative information about the PLD process.

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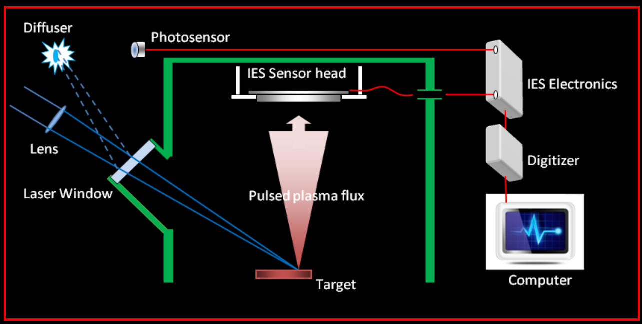
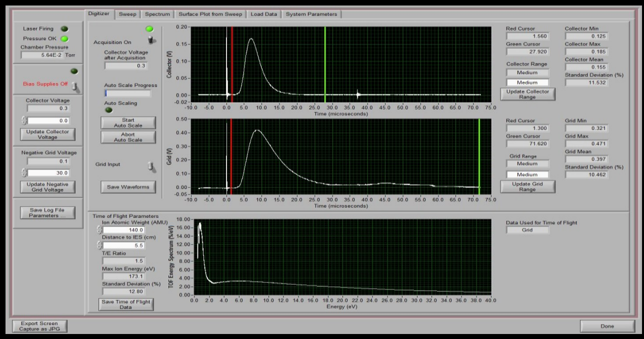
Ion Energy Spectrometer IES-200

Experimental set-up





Specifications

Parameter	Value	Units
Ion energy range	0 - 200	eV
Energy resolution	1	eV
Sweep step size	0.2 - 10	V
Ion current amplitude range	$1 \cdot 10^{-3}$ - 10	A
Sensor diameter, max	3.5	cm
Digitizer bandwidth	50	MHz
Time resolution	20	ns
Synchronization accuracy with laser	30	ns
Pulse repetition rate, max	5	Hz
Gas pressure range	0 – 0.200	Torr
Base vacuum, min	$1 \cdot 10^{-8}$	Torr
Plasma concentration, max	$\sim 1 \cdot 10^{13}$	cm^{-3}
TOF energy range	10 - 1500	eV

Special Features

- Stand-alone, computer-controlled pulsed laser-generated ion energy measurement System.
- Specialized software, integrated with Neocera PLD System software.
- Integrated universal synchronization unit: Compatible with any type of PLD laser.
- Laser pulse detection and stability analysis: Displays real-time pulse-to-pulse variations.
- Pulsed ion flux detection: Digitizes waveforms of both pulses, incoming and energy-discriminated.
- Rapid analysis of kinetic energy: In a single laser pulse, determines E_{max} for element defined by the user.
- Deposition flux stability analysis: Displays real-time statistical variation of arriving ion pulses.
- Sweep mode: Allows user control over range and step size of collector bias sweeping.
- Proprietary data processing algorithm: Allows user control over ion energy distribution N(E) and F(E).
- 3D representation of ion pulse sweep waveforms.
- Extensive data file library : Facilitates saving any pulse waveform and energy distribution for future analysis and presentation.
- Time-of-Flight mode; delivers fast turn-around spectrum in TOF approximation, from a single laser pulse, in real-time.
- Thermal ion evaluation/Analysis: Estimates concentration of low-energy ions relative to energetic ions.
- Data analysis window: Allows loading of several saved pulses or spectra for comparing.
- IES log file: Keeps track of IES runs, conditions applied, and files saved.
- Security interlocks prevent applying voltages at non-nominal pressure and/or laser conditions.

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