



# IBULE PHOTONICS



## SINGLE CRYSTAL APPLICATIONS

A world leader in the development of high performance piezoelectric single crystals and applications.



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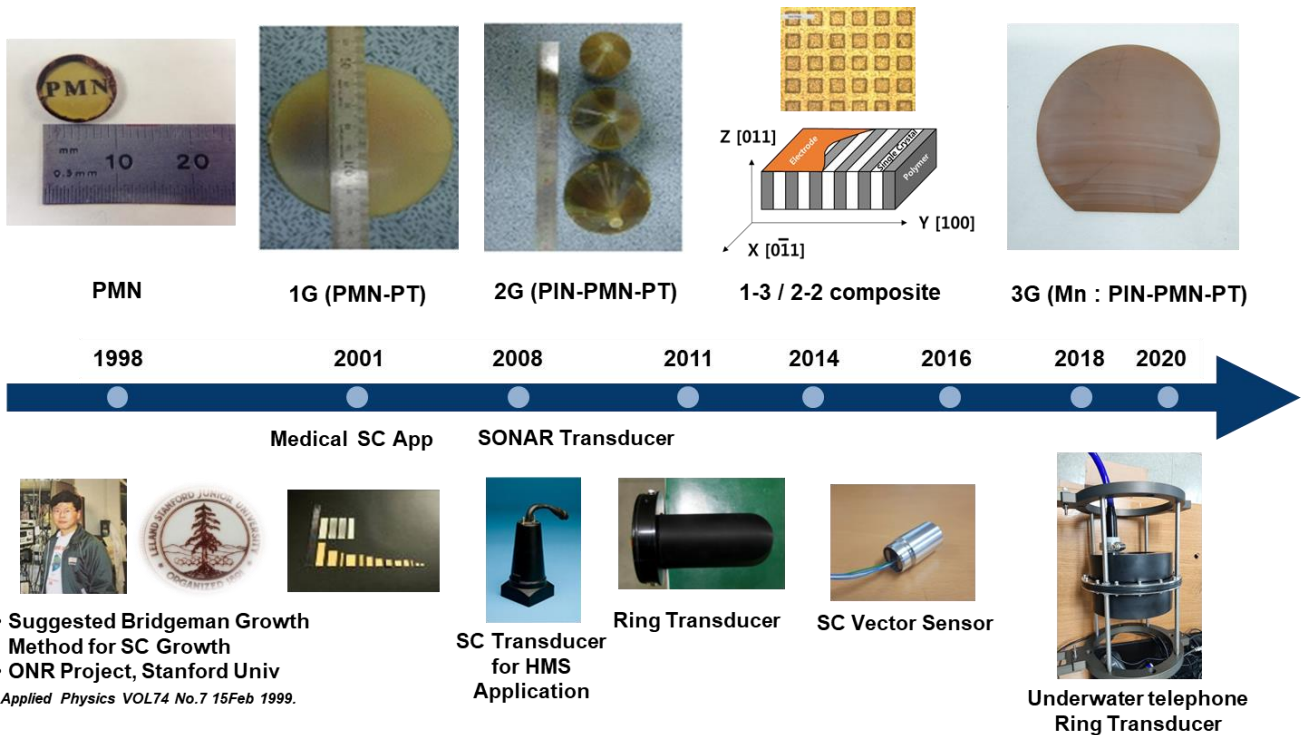
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# Company and Products

Founded in 1999, iBULe Photonics had successfully developed the **single crystal** growing technology based on the Bridgman method. Current products include 1G(PMN-PT), 2G(PIN-PMN-PT) single crystals in sizes up to **4.5" in diameter** and 3G(Mn : PIN-PMN-PT) being .

iBULe is now a world leader in the development and manufacture of high-performance single crystals, and is rapidly expanding production capacities in order to provide customers with new opportunities for the next generation of transducers for defense and commercial applications.



## Commercialization

Single Crystal and Military underwater sensor				
Ring Type	Facet Type	Bar Type		
<b>Tonpilz</b> Unmanned Underwater Vehicle (anti) Torpedo, HMS	<b>Ring Transducer</b> Underwater Telecom Torpedo Countermeasure	<b>Vector sensor</b> Towed Array SONAR System[TASS]	<b>LF projector</b> TASS	<b>Composite</b> Side Scan SONAR for UUV

# R&D Applications

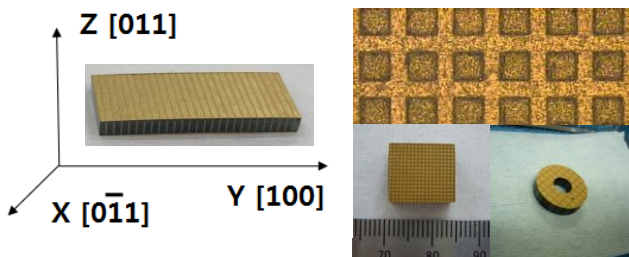
iBULE has been actively involved in the various research projects in defense and industrial applications such as SONAR transducers, NDT(Non-destructive Testing) probes, actuator, IR sensor, energy harvesting devices, accelerometer, and so on.

## Advantages of single crystals to PZT ceramics for applications

- **Increase in bandwidth and range** (50% higher coupling constants over PZT)
- **Less electric input power** (650% higher piezoconstants over PZT)
- **Reduction in overall transducer size** (78% lower elastic modulus over PZT)
- **Strong anisotropy** (piezo properties optimization by domain engineering)

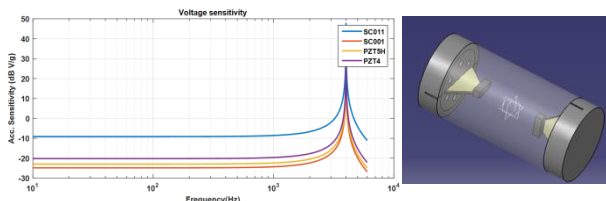
*" NUWC, Office of Naval Research(ONR) Lynn M. Ewart, et, al  
The International Symposium on Piezocrystals and their Applications July 22, 2015"*

### Single Crystal Composite



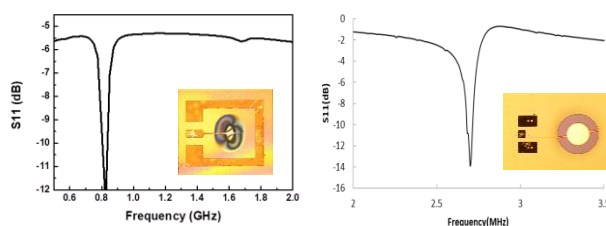
A single crystal 2-2, 1-3 composite element which is small, lightweight and conformal to hull shape for hydrophone and communication receiver on UUV or AUV or on a submarine.

### Vector Sensor / Accelerometer



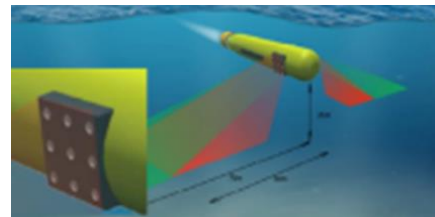
A Cylindrical hydrophone and two orthogonally mounted cantilever beam accelerometers inside the cylinder.  
Compact size and Light weight vector sensor compatible with the TAS in use

### FPSC MEMS resonator



0.8~1.5GHz resonance using [001] single crystal  
Wine-Glass mode resonators using [011] single crystal  
Wideband resonator

### Broadband Tonpilz Transducer



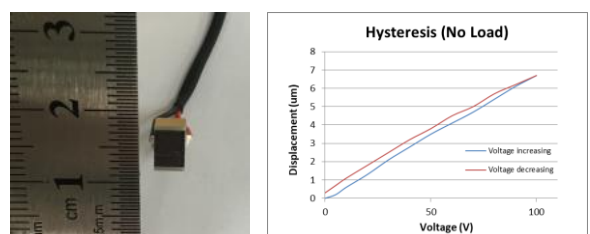
A transducer using 2-2, 1-3 composite single crystal for the potential applications to a SAS projector with a wider bandwidth and be capable of working at lower frequency than the existing one.

### Broadband Ring Transducer



A compact broadband ring transducer for the potential applications to underwater acoustic communications, countermeasure and ASW on UUV or AUV or on a submarine.

### Multilayer Actuator



Over 50 stacking of single crystal which is small size and large displacements for actuator such as 'Deformable Mirror'. (6.7um@100V)

# Single Crystal Properties

## 1G: PMN-PT

Parameter	Units	[001] poled		[011] poled	
		Low-PT	High-PT	Low-PT	High-PT
$\varepsilon_{33}^T/\varepsilon_0$	—	4842	7000	3760	5770
$d_{ij}$	$\times 10^{-12}C/N$	$d_{33}=1282$	$d_{33}=1620$	$d_{32} = -1140$	$d_{32} = -1820$
$s_{ij}^E$	$\times 10^{-12}m^2/N$	$s_{33}^E=47$	$s_{33}^E=56$	$s_{22}^E=53$	$s_{22}^E=78$
$Trt$	°C	95	85	95	85
$Ec$	$KV/cm$	2	2.5	2	2.5
Density	$kg/m^3$	8080			

## 2G: PIN-PMN-PT

Parameter	Units	[001] Poled		[011] Poled	
		Low-PT	High-PT	Low-PT	High-PT
$\varepsilon_{33}^T/\varepsilon_0$	—	4457	5666	3449	4656
$d_{ij}$	$\times 10^{-12}C/N$	$d_{33}=1226$	$d_{33}=1840$	$d_{32} = -1323$	$d_{32} = -1870$
$s_{ij}^E$	$\times 10^{-12}m^2/N$	$s_{33}^E=49$	$s_{33}^E=79$	$s_{22}^E=72$	$s_{22}^E=99$
$Trt$	°C	120	90	120	90
$Ec$	$KV/cm$	4	6	4	6
Density	$kg/m^3$	8154			

## 3G: Mn : PIN-PMN-PT

Parameter	Units	[001] Poled	[011] Poled
		Middle-PT	Middle-PT
$\varepsilon_{33}^T/\varepsilon_0$	—	4583	3747
$d_{ij}$	$\times 10^{-12}C/N$	$d_{33}=1465$	$d_{32} = -1696$
$s_{ij}^E$	$\times 10^{-12}m^2/N$	$s_{33}^E=64$	$s_{22}^E=86$
$Trt$	°C	120~130	120~130
$Ec$	$KV/cm$	6~8	8~11
Density	$kg/m^3$	8220	

Unique piezo single crystal properties create opportunities for unprecedented system performance.