THE PVLAS ANOMALY
THE PVLAS ANOMALY


>120 PAPERS
L'anomalia di PVLAS: un miraggio*

AD POLOSA
INFN ROMA `LA SAPIENZA`
M BERGANTINO, R FACCINI, L MAIANI, A MELCHIORRI, A STRUMIA.

Glossary

**Birefringence** = Generation of an ellipticity in linearly polarized light in the presence of $H$. Induction of $\xi_2$.

$$\rho_{\alpha\beta} = \frac{1}{2} \left( \begin{array}{cc} 1 + \xi_3 & \xi_1 - i\xi_2 \\ \xi_1 + i\xi_2 & 1 - \xi_3 \end{array} \right); \quad \xi_{1,2,3} \in [-1, 1]$$

$$\xi_3 = 1 \Leftrightarrow \text{lin} - y \parallel \quad \xi_1 = 1 \Leftrightarrow \text{lin} - y(45^\circ)$$

$$\xi_3 = -1 \Leftrightarrow \text{lin} - y \perp \quad \xi_1 = -1 \Leftrightarrow \text{lin} - y(-45^\circ)$$

$$\xi_2 = i \frac{A_1 A_2^* + A_2 A_1^*}{|A_1|^2 + |A_2|^2}$$

**Dichroism** = Rotation of the plane of linear polarization of light in the presence of $H$; this has to do with loss of power in a certain direction of propagation (the imaginary part of the refraction index).
THE ORIGINAL IDEA OF E. ZAVATTINI WAS TO MEASURE VACUUM DIELECTRIC PROPERTIES; IN PARTICULAR BIREFRINGENCE DUE TO PHOTON-PHOTON INTERACTIONS IN PRESENCE OF AN EXTERNAL MAGNETIC FIELD

BUT IN MPZ, PHYSICS BEYOND QED IS PROPOSED:

(dichroism + birefringence)

MPZ-DICHROISM

\[ \mathcal{L}_I = \frac{1}{4M} \phi F \cdot F \lor \frac{1}{4M} \phi F \cdot \tilde{F} \]

CONSIDER E.G. THE PSEUDOSCALAR

\[ \mathcal{L}_I \propto \phi |E_\gamma| |H_{\text{ext}}| \cos \lambda \]

see also G Raffelt and L Stodolsky, Phys. Rev. D37, 1237 (1988)
THE APPARATUS


\[ \lambda_{\text{laser}} = 1064 \text{ nm} \sim 1 \text{ eV} \]

\[ H = 5.5 \text{ T} \]

\[ P \sim 10^{-8} \text{ mbar} \]

\[ \nu_m \sim 0.3 \text{ Hz} \]

\[ \nu_{\text{SOM}} = 506 \text{ Hz} \]

\[ \epsilon_{\text{SOM}} = 10^{-3} \text{ rad} \]
MEASURING DICHROISM

\[ \text{BEYOND POLAROID P1} \]

\[ \varphi \text{ induced by } H \]

\[ \text{SUPERIMPOSE THE SOM CARRIER} \]

\[ \text{BEYOND QWP :: } \lambda/4 \]

\[ \text{E.G. FAST AXIS } \parallel \text{ P1} \]

THE EFFECT

\[ \alpha = \frac{(\kappa_\parallel - \kappa_\perp)}{2} D \sin \lambda \]

\[ I = I_0 \text{(before } P_2) \{ \sigma^2 + [\alpha(t) + \eta(t) + \Gamma(t)]^2 \} \]
\[ \alpha(t) = \alpha_0 \cos(4\pi \nu_m t + \Theta_m) \]
\[ \eta(t) = \eta_0 \cos(2\pi \nu_{\text{SOM}} t + \Theta_{\text{SOM}}) \]

\( \alpha \) (THE ROTATION TO BE DETECTED) IS EXPECTED TO BE SMALL

In the Fourier amplitude spectra of the detection photodiode signal the largest intensity comes from the term \( \alpha \eta \) (\( \eta \) gives an help) beating with

\[ \nu_{\text{SOM}} \pm 2\nu_m \]
$2V_M$

Diagram with axes $H_1$, $H_2$, and $H_3$, and a graph showing the rotation function $\cos(2\theta)$.
\[ \alpha = (3.9 \pm 0.5) \times 10^{-12 \text{ rad/pass}} \]
RESULTS AFTER QWP $\pi/2$ INVERSION

A SYSTEMATIC ERROR OCCURS
No Rotation after 45000 passes

\[
\begin{cases} 
< 1.2 \times 10^{-8} \text{ rad @ } 5.5 \ T \\
< 1.0 \times 10^{-8} \text{ rad @ } 2.3 \ T 
\end{cases}
\]

No Ellipticity after 45000 passes \(< 1.4 \times 10^{-8} @ 2.3 \ T\) while at 5.5 \(T\) still present \(... 2 \times 10^{-7} @ 5.5 \ T\)

**THESE RESULTS EXCLUDE PARTICLE INTERPRETATION OF PVLAS**
<table>
<thead>
<tr>
<th>B</th>
<th>no QWP</th>
<th>QWP 0°</th>
<th>QWP 90°</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B = 0</strong></td>
<td><img src="RUN_001402_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001411_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001420_0_1.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>B = 2.3 T</strong></td>
<td><img src="RUN_001469_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001446_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001441_0_1.png" alt="Graph" /></td>
</tr>
<tr>
<td><strong>B = 5.5 T</strong></td>
<td><img src="RUN_001500_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001502_0_1.png" alt="Graph" /></td>
<td><img src="RUN_001507_0_1.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
FORMER EXPERIMENTAL CHALLENGES
‘Axion’ Interpretation

The dichroism amplitude was proportional to $H^2$ as it should in an axion model; measured to be $\sim 10^4$ times greater than expected by QED.

\[ P_{\gamma \leftarrow \phi} = g^2 H^2 L^2 \frac{\sin^2 \left( \frac{qL}{2} \right)}{\left( \frac{qL}{2} \right)^2} \]

$q$ is the transferred momentum.

\[ \Rightarrow \epsilon = \sin 2\lambda \left( \frac{HL}{4M} \right)^2 N_{\text{pass}} \left[ \frac{\sin \left( \frac{m^2\phi L}{4\omega} \right)}{m^2\phi L/4\omega} \right]^2 \]

PVLAS claimed to observe a **scalar** (from rot. sign) with

\[ 2 \times 10^5 \text{ GeV} \lesssim M \lesssim 6 \times 10^5 \text{ GeV} \]

\[ 1 \text{ meV} \lesssim m_{\phi} \lesssim 1.5 \text{ meV} \]

Which strongly conflicts with the observation by CAST.
S. Andriamonje et al. (CAST collaboration), see review [hep-ex/0702006]
GRAVITY


\[ \mathcal{L} = y \phi \bar{\psi} \psi \]

**TAKE THE LEADING RADIATIVE CONTRIBUTION TO Y**

\[ y \sim \frac{\alpha m_p}{\pi M} \ln \left( \frac{\Lambda}{m_p} \right) \]

**THEN**

\[ V(r) \simeq G \frac{m_1 m_2}{r} \left[ 1 + \frac{1}{G m_p^2 4\pi} \left( \frac{Z}{A} \right)_1 \left( \frac{Z}{A} \right)_2 \exp(-m_{\phi}r) \right] \]

\[ m_{\phi}^{-1} = 0.2 \text{ mm} \]

\[ M \sim 4.2 \times 10^{16} \text{ GeV} \]

**EXP. < 10**{-2}
CONT’D

INCONSISTENT WITH PVLAS BY A FACTOR OF $\sim 10^{\ast\ast 11}$

$V_{ab}(r) = -\frac{g_ag_b}{4\pi r} \exp(-r/\lambda); \quad \lambda = \hbar/mc$

$$\frac{g}{\sqrt{4\pi}} \sim g_{\phi\gamma\gamma}(\frac{\alpha}{\pi} m_p)$$

$V(r) = -G\frac{m_1 m_2}{r} [1 + \alpha \exp(-r/\lambda)]$

$g_{\phi\phi\phi} \times 10^{33} = 10^{23} \text{ GeV}^{-2}$

**REGENERATION**


---

**SHINING-THROUGH-WALL EXPERIMENT**

\[
P_{\gamma \rightarrow \phi \mid qL \ll 1} \sim 2 \times 10^{-9} \left[ \left( \frac{g}{10^{-6} \text{ GeV}^{-1}} \right) \left( \frac{H}{10 \text{ T}} \right) \left( \frac{L}{10 \text{ m}} \right) \right]^2
\]

\[
(N_{\gamma}^{\text{reg}} / s) = (N_{\gamma}^{\text{FEL}} / s) \times P^2
\]

\[
(N_{\gamma}^{\text{FEL}} / s) \sim 10^{17} / s
\]

---

**REGENERATION PLANS:**

PVLAS+B2; LIPSS(JLAB); ALPS(DESY); APFEL(DESY); BMV(LULI/F); ?(CERN)
$L = 10^{40} \text{cm}^{-2} \text{sec}^{-1}$

allowing multiple collision regions in the FP

via axions

M Bergantino, R Faccini, ADP
W Buchmuller and F Hoogeveen, Phys Lett B237, 278 (1990)

WHAT ABOUT PRIMA KOFF IN A CRYSTAL?
other interpretations
A PARTIAL LIST OF MODELS

- Paraphotons and millicharged particles
- Bounds from CMB :: CMB ellipticities?
- Mohapatra-Nasri model
- Chern-Simons coupled vectors
- ...
A MICROSCOPIC POINT OF VIEW


\[
\frac{1}{M} = \frac{\alpha \epsilon^2}{\pi v} \implies \epsilon^2 \simeq 10^{-12} \frac{v}{eV}
\]

IF V IS A LOW ENERGY SCALE, WE NEED A VERY TINY CHARGE
FOR THE PARAFERMION THE `MILLICHARGE`.
QED WITH EXTRA U(1) FIELDS CAN ACCOMODATE THIS


CONSIDER A MULTIPLICATION OF U(1)’S

\[
\mathcal{L} = -\frac{1}{4} F^T \mathbf{M}_{\text{mix}} F + \frac{1}{2} A^T \mathbf{M}_{\text{mass}} A + e \sum_{i=0}^{2} j_i A_i
\]
**DIAGONALIZE**

**HYP ::**

\[ M_{\text{mix}} = \begin{pmatrix} 1 & \epsilon & \epsilon \\ \epsilon & 1 & 0 \\ \epsilon & 0 & 1 \end{pmatrix} \]

Mixings are assumed to be small making the HYP that they are induced by ultramassive fermions circulating in loops; 12 → 0

\[ U = \begin{pmatrix} 1 & \frac{m_1^2}{m_0^2-m_1^2} & \frac{m_2^2}{m_0^2-m_2^2} \\ \frac{m_0^2}{m_1^2-m_0^2} & 1 & 0 \\ \frac{m_0^2}{m_2^2-m_0^2} & 0 & 1 \end{pmatrix} \]

We can rotate, by \( U \), the (para)photons fields in such a way to obtain the kinetic part in the standard F.F form -- keep up to first order in \( \epsilon \)

**HYP ::**

\[ e_2 = -e_1 = -e \]
RECONCILING WITH STARS

\[ m_0^2 \rightarrow q^2 \]
\[ m_1^2 \rightarrow 0 \]
\[ m_2^2 \rightarrow \mu^2 \]

\[ e \xrightarrow{\gamma_1} \epsilon \xrightarrow{\gamma} f \]
\[ -e \xrightarrow{\gamma_2} \epsilon \xrightarrow{\gamma} f \]
\[ = \epsilon e \frac{\mu^2}{q^2 - \mu^2} \xrightarrow{\tilde{\gamma}} f \]

\[ q_{\text{eff}} = e \epsilon \quad \text{(vacuum)} \]
\[ q_{\text{eff}} = e \epsilon \frac{\mu^2}{q^2} \quad \text{small provided} \quad \omega_P(\sim \text{KeV}) \gg \mu \]

\[ \epsilon \frac{\mu^2}{eV^2} < 4 \times 10^{-8} \quad \text{HBstars} \]
GRAVITY AGAIN


-ALP DOES NOT HAVE A DIRECT COUPLING TO PHOTONS

-ALP-PHOTONS VERTEX ARISES BECAUSE OF A PHOTON-PARAPHOTON MIXING $\epsilon$

-A PARAPHOTON MASS $\mu$ INDUCES AN EFFECTIVE PHOTON FORM FACTOR SUCH THAT THE COUPLING IS REDUCED FOR $q >> \mu$

$$V(r) \simeq G \frac{m_1 m_2}{r} \left[ 1 + \frac{4}{G m_p^2} \frac{y'^2}{4\pi} \left( \frac{Z}{A} \right)_1 \left( \frac{Z}{A} \right)_2 \exp(-m_\phi r) \right] \quad m_\phi^{-1} = 0.2 \text{ mm}$$

SINCE $y'$ IS SMALLER THAN $y$, BY $\mu/m_p$, A SMALLER VALUE OF $M$ IS ALLOWED!

$M \sim 10^{5 \text{ GeV}}$
MILLICHARGES & DICHROISM


\[ \gamma(\text{lin pol}) \rightarrow e^+ e^- \text{ with } \omega > 2m_e \text{ in } H^{\text{ext}} \]

\[ \Rightarrow \text{dichroism} \]

NEVER OBSERVED IN LAB BECAUSE OF THE THRESHOLD

IN PVCAS \( \omega > 2m_e \)

\[ \Delta \lambda \simeq \frac{1}{4} (\kappa_\parallel - \kappa_\perp) L \sin(2\lambda) \]

NB. THE LANDAU LEVELS ARE VERY DENSE HERE :: NO ABSORPTION PEAKS EXPECTED

The propagation speed of the laser photons is slightly changed in the magnetic field owing to the coupling to virtual charged pairs.

\[ \Delta \phi = (n_\parallel - n_\perp) \omega L \]


See also SN Gninenko, NV Krasnikov and A Rubbia, Phys. Rev. D75, 075014 (2007)
COSMIC BOUNDS


::HYP::

-COSMOLOGY AFTER DECOUPLING
-ONLY SM PARTICLES AT BEGINNING
START PRODUCING MILlichARGED BY PHOTONS

\[
\frac{n_e}{n_\gamma} \ll 1 \quad \text{after decoupling}
\]

\[
\Gamma \sim \langle n_\gamma \sigma_{\gamma\gamma \rightarrow \epsilon \bar{\epsilon} \nu} \rangle_T \sim T
\]

\[
n_\gamma = \left( \frac{2\zeta(3)}{\pi^2} \right) T^3
\]

\[
H = \frac{\dot{a}}{a} \sim T^{3/2}
\]

\[
\Gamma/H \text{ maximal at low } T : : T_* \sim \max(T_0, m_\epsilon)
\]
WE EXPECT AN ENERGY DEPENDENT DEPLETION OF THE CMB SPECTRUM

\[ f(E) \equiv \text{(small) deviation from } f_{BE}(E) \]
\[ r(E) \equiv f(E) / f_{BE}(E) \]
\[ x \equiv E / T \]

\[ f_{BE}(E) H \frac{d}{d \ln z} r(x) = -\frac{f(E)}{4E} \int dp' f(E') \tilde{\sigma}(s) \rightarrow n_{\gamma} H \frac{d}{d \ln z} \frac{n_{\gamma}^{\text{dev}}}{n_{\gamma}} = -\gamma T \]

EXPECT SMALL SPECTRAL DISTORTIONS

\[ H \frac{d}{d \ln z} r(x) = \frac{T}{32\pi^2 x} \int dc\theta dx' x' f_{BE}(x') \tilde{\sigma}(s = 2xx'T^2(1 - c\theta)) \]
FITTING FIRAS

AS A RESULT ONE FINDS THAT

\[ Y \equiv \frac{n_\epsilon}{n_\gamma} \lesssim 6 \times 10^{-5} \text{ at } 3\sigma \text{ c.l. for } m_\epsilon = 0.1 \text{ eV} \]

FOR GENERAL MASSES AND CHARGES

ISOCURVES OF Y
MODEL DEPENDENT EXCLUSION

ONCE MILlichARGES HAVE BEEN PRODUCED THEY CAN START DISINTEGRATING INTO PARAPHOTONS PAIRS -- GOING RAPIDLY TO THERMAL EQUILIBRIUM -- BUT STILL THEY CAN KEEP ON DEPLETING CMB VIA

\[ \gamma_{\text{CMB}} \epsilon \rightarrow \gamma' \epsilon \]

OTHER BOUNDS CAN BE STUDIED

\[ Y_{\gamma}^{\text{depletion}} \sim \min \left[ 1, \sigma(\gamma\epsilon \rightarrow \gamma'\epsilon) \frac{Y_{\epsilon} n_{\gamma}(T_{*})}{H(T_{*})} \right] \]

\[ \sigma(\gamma\epsilon \rightarrow \gamma'\epsilon) \sim \frac{\epsilon^2 \epsilon'^2 e^4}{4\pi T_{*}^2} \]

\[ \epsilon' \sim O(1) ? \]

DEPENDING ON THE PARAPHOTON MODEL ...
Spectral modification of a gamma-TeV source at the galactic center. Photon-axion oscillations cause a downward shift of the high energy spectrum (a change of normalization of the typical power spectrum between low and high energies).

\[ \frac{dN}{dE} \sim E^{-\Gamma} \]
\[ \Gamma = 2.25 \] solid line
MORE SCALARS


\[ \Phi(S), \sigma(S), \phi(PS) \]

\[ \frac{\Phi \phi}{M^2} F \cdot \tilde{F} \text{ rather than } \frac{\phi}{M} F \cdot \tilde{F} \]

BUT

\[ \frac{\Phi \phi}{M^2} F \cdot \tilde{F} \mapsto \frac{\phi}{M_{\text{PVLAS}}} F \cdot \tilde{F} \text{ if } T < \text{keV} \]

HYP :: LOW TEMPERATURE PHASE TRANSITION

\[ \frac{\langle \Phi \rangle}{M^2} = \frac{1}{M_{\text{PVLAS}}} \]

IN THE SUN IT IS PH.S. INHIBITED ALSO THE PROCESS

\[ \gamma \gamma \rightarrow \Phi \phi \text{ if } m_{\Phi} \sim 10 \div 50 \text{ MeV} \]

\[ M^{**2} \sim 10^{**5} \text{ GeV}^{**2} \text{ is consistent with cosmological & astrophysical data} \]
A VECTOR

I Antoniadis, A Boyarsky, O Ruchayskiy, hep-ph/0606306

\[ \kappa \sim 10^{-17} \] suppress axions from stars

**PVLAS DICHROISM?**

PVLAS birefringence \( \propto m_{(H)}^{\gamma} \sim \frac{\kappa H}{m_{\phi}} \)

\[ m_{\phi} \sim \kappa \nu_{\phi} \text{ and } m_{\phi} \to 0 \text{ as } \kappa \to 0 \]

IN A C.S. LAGRANGIAN

\[
\mathcal{L} = -\frac{1}{4} F_{A}^{2} - \frac{1}{4} F_{\phi}^{2} + m_{\gamma}^{2} / 2 A^{2} + m_{\phi}^{2} \phi^{2} - 2 \kappa \epsilon(A, \phi; F_{A})
\]

WHAT IF A VECTOR AXION IS PRODUCED WITH LONGITUDINAL POLARIZATION?

\[
\epsilon_{\parallel}^{\mu} = \left( \frac{|k|}{m_{\phi}}, \frac{\omega \vec{k}}{m_{\phi} |\vec{k}|} \right)
\]

MAYBE OK WITH PVLAS DICHROISM BUT AGAIN AT ODDS WITH STARS?
CONCLUSIONS I (BEFORE 23/6)

- EXPERIMENTALLY DRIVEN FIELD :: MAYBE WE ARE CLOSE TO A FINAL ANSWER TO CONFIRM/DISPROVE THE PVLAS RESULT*

- ALL THEORETICAL MODELS HERE DESCRIBED SEEM TO HAVE TROUBLES WITH DATA

- I HAVE NOT MENTIONED OTHER MODELS LIKE THE CHAMELEON BY BRAX ET AL. [...]

CONCLUSIONS II

 EXPERIMENTALLY DRIVEN FIELD :: PVLAS DISPROVES PVLAS*

 ALL THEORETICAL MODELS HERE DESCRIBED SEEM TO HAVE TROUBLES WITH DATA :: IT SEEMS THAT NOW WE KNOW WHY

*PVLAS arXiv:0706.3419
THE MPZ CALCULATION
CONVERSION PROBABILITY

\[
\begin{aligned}
\Box A + \frac{1}{M} B_\perp \dot{\phi} &= 0 \\
(\Box + m^2) \phi - \frac{1}{M} B_\perp \cdot \dot{A} &= 0
\end{aligned}
\]

LOOK FOR SOLUTIONS

\[
A = A_\parallel i + A_\perp j
\]

\[
A_\perp = A_\perp 0 e^{-i|k|t + ikz}
\]

MIXING AXION AND A_\parallel

\[
\psi = \begin{pmatrix} A_\parallel \\ \phi \end{pmatrix} = \begin{pmatrix} \lambda \\ \mu \end{pmatrix} e^{-i\omega t + ikz} \equiv u \ e^{-i\omega t + ikz}
\]

AND SOLVE THE LINEAR SYSTEM

\[
M u = 0
\]

\[
M = \begin{pmatrix} k^2 - \omega^2 & -i \frac{B}{M} \omega \\ i \frac{B}{M} \omega & k^2 + m^2 - \omega^2 \end{pmatrix}
\]

THE SECULAR DETERMINANT:

\[ \omega_{\pm}^2 = k^2 + \frac{1}{2} \left[ m^2 + \frac{B^2}{M^2} \pm \sqrt{\left( m^2 + \frac{B^2}{M^2} \right)^2 + 4 \frac{k^2 B^2}{M^2}} \right] \]

\[ \lambda_{\pm} = \frac{i \omega_{\pm} B}{M} \frac{1}{k^2 - \omega_{\pm}^2} \]

\[ u_{\pm} = \begin{pmatrix} \lambda_{\pm} \\ 1 \end{pmatrix} \]

INITIAL CONDITION :: 0-AXIONS

\[ A_{\parallel} (t = z = 0) = \cos \lambda \]
\[ \phi(t = z = 0) = 0 \]

\[ A_{\parallel} = \cos \lambda \left[ \epsilon e^{-i \omega_+ t} + (1 - \epsilon) e^{-i \omega_- t} \right] e^{ikz} \]
\[ \phi = \cos \lambda \Phi \left[ e^{-i \omega_+ t} + e^{-i \omega_- t} \right] e^{ikz} \]

\[ \epsilon = \frac{\omega_+ (k^2 - \omega_-^2)}{D(k)} \]
\[ \Phi = -\frac{i M}{B} \frac{(k^2 - \omega_+^2)(k^2 - \omega_-^2)}{D(k)} \]
\[ D(k) = \omega_+(k^2 - \omega_-^2) - \omega_-(k^2 - \omega_+^2) \]
\[ \epsilon \sim \frac{B^2}{M^2} \text{ small} \]
EXPANDING IN THE SMALL PARAMETER

\[|A_\parallel| = \cos \lambda \left[ 1 - 2 \epsilon \sin^2 \left( \frac{\Delta \omega L}{2} \right) \right] \]

\[= \cos \lambda \left[ 1 - 2 \left( \frac{BL}{4M} \right)^2 \frac{\sin^2 x}{x^2} \right]_{x = L\Delta \omega/2 < 1} \]

PROCEED SIMILARLY FOR $|\Phi|$

DICHROISM

\[P_{\phi \to \gamma} \equiv \frac{|\phi|^2}{|A_\parallel(t = z = 0)|^2} \]
THE SOM (STRESS OPTIC MODULATOR) IS A NEW TYPE OF POLARIZATION MODULATOR DEVICED WITHIN THE PVLAS COLLABORATION: IT INDUCES A CONTROLLABLE BIREFRINGENCE ON A GLASS WINDOW BY MEANS OF AN ELECTRICAL STRESS APPLIED TO IT.


THE MODULATION OF ELLIPTICITY TO BE MEASURED IS AT VERY LOW FREQUENCY, WHERE 1/F NOISE AND OTHER SOURCES OF LOW FREQ. NOISE ARE DANGEROUS.

THE ELLIPTICITY MODULATED THROUGH A MAGNETIC FIELD MODULATION BEATS WITH KNOWN ELLIPTICITY INDUCED ON LIGHT USING A POLARIZATION MODULATOR (SOM)